

**TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371**

ATTORNEY'S DOCKET NUMBER  
13377-002001

U.S. APPLICATION NO. (If Known, see 37 CFR 1.5)

**09/890306**

INTERNATIONAL APPLICATION NO.  
CT/AU00/00046

INTERNATIONAL FILING DATE  
28 January 2000

PRIORITY DATE CLAIMED  
29 January 1999

TITLE OF INVENTION

METHOD OF CONTROLLING FUNGAL PATHOGENS, AND AGENTS USEFUL FOR SAME

APPLICANT(S) FOR DO/EO/US

Murali Nayudu and Rajvinder Kaur

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).
4. ☐ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☒ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 16 below concern other documents or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.  
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☐ Other items or information:

☐  
☐  
☐  
☐  
☐

**CERTIFICATE OF MAILING BY EXPRESS MAIL**

Express Mail Label No. **EL485712985US**

I hereby certify under 37 CFR §1.10 that this correspondence is being deposited with the United States Postal Service as Express Mail Post Office to Addressee with sufficient postage on the date indicated below and is addressed to the Commissioner for Patents, Washington, D.C. 20231.

Date of Deposit

**July 27, 2001**

Signature

**Samantha Bell**

Typed Name of Person Signing

**Samantha Bell**

APPLICATION NO. (IF KNOWN) <div style="font-size: 1.5em; font-weight: bold;">097890306</div>		INTERNATIONAL APPLICATION NO. PCT/AU00/00046		ATTORNEY'S DOCKET NUMBER 13377-002001	
<input checked="" type="checkbox"/> The following fees are submitted:  <b>Basic National Fee ( 37 CFR 1.492(a)(1)-(5) ):</b>  Either international preliminary examination fee (37 CFR 1.482) or international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... <b>\$1000</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... <b>\$860</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... <b>\$710</b>  International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... <b>\$690</b>  International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) ..... <b>\$100</b>				<b>CALCULATIONS PTO USE ONLY</b>	
<b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>				\$860.00	
Surcharge of <b>\$130</b> for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$0.00	
Claims	Number Filed	Number Extra	Rate		
Total Claims	70 - 20 =	50	x \$18	\$900.00	
Independent Claims	8 - 3 =	5	x \$80	\$400.00	
MULTIPLE DEPENDENT CLAIMS(S) (if applicable)			+ \$270	\$0.00	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$2,160.00	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				\$0.00	
<b>SUBTOTAL =</b>				\$2,160.00	
Processing fee of <b>\$130</b> for furnishing the English Translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f))				\$0.00	
<b>TOTAL NATIONAL FEE =</b>				\$2,160.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). <b>\$40.00</b> per property +				\$0.00	
<b>TOTAL FEES ENCLOSED =</b>				\$2,160.00	
<b>Amount to be refunded:</b>				\$	
<b>Charged:</b>				\$	
a. <input checked="" type="checkbox"/> A check in the amount of \$2,160.00 to cover the above fees is enclosed. b. <input type="checkbox"/> Please charge my Deposit Account No. 06-1050 in the amount of \$0.00 to cover the above fees. A duplicate copy of this sheet is enclosed. c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 06-1050. A duplicate copy of this sheet is enclosed.					
<b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive          (37 CFR 1.137(a) or (b) must be filed and granted to restore the application to pending status.</b>					
<b>SEND ALL CORRESPONDENCE TO:</b>					
Y. Rocky Tsao FISH & RICHARDSON P.C. 225 Franklin Street Boston, MA 02110-2804 (617) 542-5070 phone (617) 542-8906 facsimile			SIGNATURE: NAME: Y. Rocky Tsao REGISTRATION NUMBER: 34,053		

Vonda



PCT09

## RAW SEQUENCE LISTING

DATE: 04/11/2002

PATENT APPLICATION: US/09/890,306

TIME: 16:03:04

Input Set : A:\13377-002001.TXT

Output Set: N:\CRF3\04112002\I890306.raw

ENTERED

4 <110> APPLICANT: Nayudu, Murali  
 5 Kaur, Rajvinder  
 7 <120> TITLE OF INVENTION: A METHOD OF CONTROLLING FUNGAL  
 8 PATHOGENS, AND AGENTS USEFUL FOR SAME  
 11 <130> FILE REFERENCE: 13377-002001  
 13 <140> CURRENT APPLICATION NUMBER: 09/890,306  
 C--> 14 <141> CURRENT FILING DATE: 2002-03-07  
 16 <150> PRIOR APPLICATION NUMBER: PCT/AU00/00046  
 17 <151> PRIOR FILING DATE: 2000-01-28  
 19 <150> PRIOR APPLICATION NUMBER: AU PP 8394  
 20 <151> PRIOR FILING DATE: 1999-01-29  
 22 <160> NUMBER OF SEQ ID NOS: 6  
 24 <170> SOFTWARE: FastSEQ for Windows Version 4.0  
 26 <210> SEQ ID NO: 1  
 27 <211> LENGTH: 757  
 28 <212> TYPE: DNA  
 29 <213> ORGANISM: Pseudomonas sp.  
 31 <400> SEQUENCE: 1  
 32 gctgacagca ccacgccggc cagcaccgtg tgcccgcgtc gcatttttcoct gccgaccgcc 60  
 33 gacactcgcc tgatcgccct caatgccgca cgggcaagat gtgcgaagac ttcggtgaca 120  
 34 aaggccaggt cgacctgagc gccaacatcg gtggtttcac cgcgggcggg tactactcca 180  
 35 cctcgccctcc ggccgttacc cagaacctgg tggatgatcg cggccacgtc accgacaacg 240  
 36 ttccaccga cgaaccacgc ggcgtcatcc gcgcctacga cgtgcacacc ggcaagttgg 300  
 37 tgtggaactg ggacagcggc aagccggagc acaccacgcc gatcgccgag gccagactt 360  
 38 acaccgcgaa ttgcgccgaa atgtggtcca tgttcagcgt cgatgaaaaa cttggcatgc 420  
 39 tctacctgcc aatgggcaac cagacccccg accagttcgg ttgctgcgta ccccggaatc 480  
 40 ggaaaaatac tccgccggcc tgaccgcgct ggacatcgcc accggcaagg tgcgctggta 540  
 41 cttcagttca cccaccacga cctgtgggac atggacgtcg gcggtcaacc gaccctgatg 600  
 42 gacatgaaga ccgccgacgg cgtgaaacgg gccgtactgg cctcgacaaa caagggaag 660  
 43 catctacgtg ctggaccgca gcaacggcca gccgatcatt ccgatcaagg aaatccccgg 720  
 44 tgcccgcgaag gtgccgggtg gaaggcgaac aacacct 757  
 46 <210> SEQ ID NO: 2  
 47 <211> LENGTH: 508  
 48 <212> TYPE: DNA  
 49 <213> ORGANISM: Pseudomonas sp.  
 51 <220> FEATURE:  
 52 <221> NAME/KEY: misc\_feature  
 53 <222> LOCATION: 403  
 54 <223> OTHER INFORMATION: n = A,T,C or G  
 56 <400> SEQUENCE: 2  
 57 tactgtgccg cgcctggggc cgcaggctgc cgttgcgaaa acctgcgcaa ttggcgcaaa 60  
 58 gcagttccat tgaggaaaac cgcgcccagc ggcggaacct agaattctgca ccaacatggc 120  
 59 cgtcccatct gcaaaccgaa ataaaaaacg ccccggtgta ccgaggcggt tgctgcgcat 180

## RAW SEQUENCE LISTING

DATE: 04/11/2002

PATENT APPLICATION: US/09/890,306

TIME: 16:03:04

Input Set : A:\13377-002001.TXT

Output Set: N:\CRF3\04112002\I890306.raw

```

60 tcaaccgact gcagcaatca acggctggcg aagtacatgg tgacttcgaa accgatacgc 240
61 aggtcgatat atgcgggttt ggaccaggac atggaaatac tcctttggtt ggggtgggac 300
62 ggttgagatc tatacatata gtccacctcc gttcggagat gttcagatgc ttaggctgct 360
63 atgggtactaa attaaacaaa atcgacgccc tcgattctcc ganaaaagct cattgcagac 420
64 gctggaatga tcatttcggc atgtgccaat gttcatcccg ggcaaacacc gttgctcagg 480
65 caataccggc caccttcggc gtcgatca 508
67 <210> SEQ ID NO: 3
68 <211> LENGTH: 660
69 <212> TYPE: DNA
70 <213> ORGANISM: Pseudomonas sp.
72 <400> SEQUENCE: 3
73 ttaattogta ggccatgctc atcgcatoga gcatgctcca gagaatgtcc agcttgaact 60
74 ggagaatctc cagcatgtgc tcctggcccg cgcgggtggt gtaatgtgc aaggtaatcg 120
75 ccaggccatg ctccacgtca cggcgggctt gaccgaggcg ggtgcggaag tattcataac 180
76 cggccggatc gatccacggg tagtgctgtg gccaaactgtc caggcgcgac tgatggatct 240
77 gcggcgcgaa cagctcggtc agcagactac tggcggcttc ctgccaaactg gcccggcgag 300
78 cgaagttgac gtaggcatcc acggcgaatc gcacccctgg cagcaaccaat tcctgggagc 360
79 gcagttgacg gggatccaac cccacggcct ggcccaaccg cagccaggcc tcgatgccgc 420
80 cgtcttcgcc ggggtgcgcc tcattggtga gcaggcgctg gatccactcg cgacggatct 480
81 cccgatccgg gcagttggcc aggatcgccg catccttcag cggaatgttc acctgatagt 540
82 aaaagcgggt ggcgaccag ccctggattt gctcgcgagt ggcaaggcct tcatacatcg 600
83 ccacgtgata cggatgatgg atgtggtaat acgcgccctt ggcttcgcag ggcccgtttc 660
85 <210> SEQ ID NO: 4
86 <211> LENGTH: 315
87 <212> TYPE: DNA
88 <213> ORGANISM: Pseudomonas sp.
90 <400> SEQUENCE: 4
91 taaggatgca caaaacaaa acccctcgct ggcgcccccg ctatcgcttc cagtacgaac 60
92 cggcgcagaa aggtcatgtg ttgctctatc ctgaaggcat gatcaagctc aacgacagcg 120
93 ctgcgctgat cggcggcctg atcgacggtg aacgggatgt cgcagccatc atcggcgagc 180
94 tggccaagca gtttcccgac gtgccgaac tcggtgacga catcgagcag ttcattggag 240
95 tcgcccgtgc agagcattgg atcgaacttg cctgaccagc cagcgatcgg cttgccgctg 300
96 tggttgctgg cggag 315
98 <210> SEQ ID NO: 5
99 <211> LENGTH: 810
100 <212> TYPE: DNA
101 <213> ORGANISM: Pseudomonas sp.
103 <400> SEQUENCE: 5
104 tgcaggtggc gagctcgacg aagtggcct caagggcaat gcacagctcg atgatgcggt 60
105 cgatcttgct gatgttgctc cgatgggtaa cgaagttgag caccatcggg tagccgtggg 120
106 ccttcaactgc cggggccatt tccagcttct gtgcgaaggc tttcttcgag ccggccagca 180
107 ggttggttac ctgttcgtcg ctggcctgga agctgatctg gatatgatcg aggccggcct 240
108 tcttgaaagtc gctgattttc tgttcggtoa aaccgatgcc ggagggtgac aggttggtgt 300
109 agaaacccaa cttgcgcgcc tcgccgatca gttcggcgag gtccctggcg accagcggtt 360
110 cgccaccgga aaagcccagc tgcgcggcgc ccatttccct ggcttcgcga aagacctga 420
111 accactgctc ggtgctcagc tccttgccct gctcggcgaa gtccagcggg ttggaacagt 480
112 aggggcattg cagcgggcaa cgataggtca gctccgccag caaccacagc ggcaagccga 540
113 tcgctggctg gtcaggcaag ttcgatocaa tgctctgcac ggcgcacctc catgaactgc 600
114 tcgatgtcgt caccgagttc ggcacgtcgg gaaactgggt gccagctcg ccgatgatgg 660

```

## RAW SEQUENCE LISTING

DATE: 04/11/2002

PATENT APPLICATION: US/09/890,306

TIME: 16:03:04

Input Set : A:\13377-002001.TXT

Output Set: N:\CRF3\04112002\I890306.raw

```
115 ctgcgacata ccgttacgt cgatcaggcc cgccgatcaa cgcaacgctt gcgttgaact 720
116 tgatcatgcc tticaggaaa aaaacaaaca catgaccttt gtgcgcccgg ttcgtacttg 780
117 gaaagcgata agccggggcc gccaacgaa 810
119 <210> SEQ ID NO: 6
120 <211> LENGTH: 354
121 <212> TYPE: DNA
122 <213> ORGANISM: Pseudomonas sp.
124 <400> SEQUENCE: 6
125 gttactaaat taaacaaaat cgcacgcctc gattctccga gaaagctcat tgcagacgct 60
126 gtaatgatca tticggcatg tgccaatggt catccgggca aacaccgttg ctcaggcaat 120
127 accggccacc tticggcgctg atcaggcgct gggtggcatc gagcaattgc ttgcgattca 180
128 atcctgcgat cgcacgcaa agttgctcaa ggtaatccga cggcgggccg gccagtttac 240
129 cctgccaaag caattcgcc gttgggcgca gggcaagggt tcgcttgtga aactgggagg 300
130 cgaagtgcc gttgctgggt cgagcaaggt cgaatcgctg acctgtcgga tcag 354
```

Total: 505050

## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Murali Nayudu et al                      Art Unit : Unknown  
Serial No. : 09/890,306                              Examiner : Unknown  
Filed : July 27, 2001  
Title : A METHOD OF CONTROLLING FUNGAL PATHOGENS, AND AGENTS  
USEFUL FOR SAME

**BOX PCT**

Commissioner for Patents  
Washington, D.C. 20231

VERIFIED STATEMENT UNDER 37 CFR §1.821(f)

I, Katica Magovcevic, declare that I personally prepared the paper and the computer-readable copy of the Sequence Listing filed herewith for the above-identified application and that the content of both is the same.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of The United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: 3/7/02

Katica Magovcevic  
Katica Magovcevic

Fish & Richardson P.C.  
225 Franklin Street  
Boston, Massachusetts 02110-2804  
(617) 542-5070 telephone  
(617) 542-8906 facsimile

20399460.doc

## CERTIFICATE OF MAILING BY EXPRESS MAIL

Express Mail Label No. EL 940 866 328 US

I hereby certify under 37 CFR §1.10 that this correspondence is being deposited with the United States Postal Service as Express Mail Post Office to Addressee with sufficient postage on the date indicated below and is addressed to the Commissioner for Patents, Washington, D.C. 20231.

March 7, 2002  
Date of Deposit  
Signature Henry Jenkins  
Typed or Printed Name of Person Signing Certificate Henry Jenkins

## SEQUENCE LISTING

<110> Nayudu, Murali  
Kaur, Rajvinder

<120> A METHOD OF CONTROLLING FUNGAL  
PATHOGENS, AND AGENTS USEFUL FOR SAME

<130> 13377-002001

<140> 09/890,306

<141> 2001-07-27

<150> PCT/AU00/00046

<151> 2000-01-28

<150> AU PP 8394

<151> 1999-01-29

<160> 6

<170> FastSEQ for Windows Version 4.0

<210> 1

<211> 757

<212> DNA

<213> Pseudomonas sp.

<400> 1

gctgacagca ccacgccggc cagcaccgtg tgcccgcgtc gcatttttct gccgaccgcc	60
gacactcgcc tgatcgccct caatgccgca ccggcaagat gtgcgaagac ttcggtgaca	120
aaggccaggc cgacctgagc gccaacatcg gtggtttcac cgcgggcggc tactactcca	180
cctcgccctcc ggccgttacc cagaacctgg tggatgatcg cggccacgac accgacaacg	240
tttccaccga cgaaccacgc ggcgtcatcc gcgcctacga cgtgcacacc ggcaagttgg	300
tgtggaactg ggacagcggc aagccggacg acaccacgcc gatcgccgag ggccagactt	360
acaccgcaa ttccgccgaac atgtggtcca tggtcagcgt cgatgaaaaa cttggcatgc	420
tctacctgcc aatgggcaac cagacccccg accagttcgg tggctgcgta ccccggaatc	480
ggaaaaatac tccgccggcc tgaccgcgct ggacatcgcc accggcaagg tgcgctggta	540
cttcagtcca cccaccacga cctgtgggac atggacgtcg gcggtcaacc gacctgatg	600
gacatgaaga ccgccgacgg cgtgaaaccg gccgtactgg cctcgacaaa caagggcaag	660
catctacgtg ctggaccgca gcaacggcca gccgatcatt ccgatcaagg aaatccccgg	720
tgcccgcgaag gtgccggtgg gaaggcgaac aacacct	757

<210> 2

<211> 508

<212> DNA

<213> Pseudomonas sp.

<220>

<221> misc\_feature

<222> 403

<223> n = A,T,C or G

<400> 2

tactgtgccg cgctggggcc cgcaggctgc cgttgcgaaa acctgcgcaa ttggcgcaaa

60

FastSEQ for Windows Version 4.0

gcagttccat	tgaggaaaac	cgcgcccagc	ggcggaacct	agaatctgca	ccaacatggc	120
cgctccatct	gcaaaccgaa	ataaaaaacg	ccccgggtga	cagaggcggt	tgctgcgcat	180
tcaaccgact	gcagcaatca	acggctggcg	aagtacatgg	tgacttcgaa	accgatacgc	240
aggctgatat	atgcgggttt	ggaccaggac	atggaaatac	tcctttgggt	ggggtgggac	300
ggttgagatc	tatacatata	gtccacctcc	gttcggagat	gttcagatgc	ttaggctgct	360
atggtactaa	attaaacaaa	atcgacgccc	tcgattctcc	ganaaaagct	cattgcagac	420
gctggaatga	tcatttcggc	atgtgccaat	gttcatcccg	ggcaaacacc	gttgctcagg	480
caataccggc	caccttcggc	gtcgcata				508

&lt;210&gt; 3

&lt;211&gt; 660

&lt;212&gt; DNA

&lt;213&gt; Pseudomonas sp.

&lt;400&gt; 3

ttaattcgta	ggccatgctc	atcgcatcga	gcattgctcca	gagaatgtcc	agcttgaact	60
ggagaatctc	cagcatgtgc	tcctggcccc	cgcggttggt	gtaatgtgc	aaggtaatcg	120
ccaggccatg	ctccacgtca	cggcgggcct	gaccgaggcg	ggtgcggaag	tattcataac	180
cggccggatc	gatccacggg	tagtgctgtg	gccaaactgtc	caggcgcgac	tgatggatct	240
gcgccgcgaa	cagctcggtc	agcgagctac	tggcggttc	ctgccaaactg	gcccggcgag	300
cgaagttgac	gtaggcatcc	acggcgaatc	gcacccctgg	cagcaccaat	tcctgggagc	360
gcagttgac	gggatccaac	cccacggcct	ggcccaaccg	cagccaggcc	tcgatgccgc	420
cgtcttcgcc	gggtgcgcgc	tcattggtoga	gcaggcgctg	gatccactcg	cgacggatct	480
cccgatccgg	gcagttggcc	aggatcgccg	catccttcag	cggaatgttc	acctgatagt	540
aaaagcggtt	ggcgacccag	ccctggattt	gctcgcgagt	ggcacggcct	tcatacatcg	600
ccacgtgata	cggatgatgg	atgtggtaat	acgcgcctt	ggcttcgcag	ggcccgttcc	660

&lt;210&gt; 4

&lt;211&gt; 315

&lt;212&gt; DNA

&lt;213&gt; Pseudomonas sp.

&lt;400&gt; 4

taaggatgca	caaaacccaa	accctcgcct	ggcgccccgg	ctatcgcttc	cagtacgaac	60
cggcgagaaa	aggtcatgtg	ttgctctatc	ctgaaggcat	gatcaagctc	aacgacagcg	120
ctgcgctgat	cggcgccctg	atcgacgggt	aacgggatgt	cgcagccatc	atcgccgagc	180
tggccaagca	gtttcccgac	gtgcccgaac	tcggtgacga	catcgagcag	ttcatggagg	240
tcgcccgtgc	agagcattgg	atcgaacttg	cctgaccagc	cagcgatcgg	cttgccgctg	300
tggttgctgg	cggag					315

&lt;210&gt; 5

&lt;211&gt; 810

&lt;212&gt; DNA

&lt;213&gt; Pseudomonas sp.

&lt;400&gt; 5

tgcagggtggc	gagctcgacg	aagtcggcct	caagggaat	gcacagctcg	atgatgcggt	60
cgatcttgctc	gatgttgctc	cgatgggtaa	cgaagttgag	caccatcggt	tagccgtggg	120
ccttcaactgc	ccgggocatt	tcagcttct	gtgcgaaggc	tttcttcgag	ccggccagca	180
ggttggtcac	ctgttcgtcg	ctggcctgga	agctgatctg	gatatgatcg	aggccggcct	240
tcttgaaagt	gctgatttcc	tggttcggtc	aaccgatgcc	ggaggtgatc	aggttggtgt	300
agaaacccaa	cttgcgcgc	tcgcccgaac	gttcggcgag	gtcctggcgc	accagcggtt	360
cgccaccgga	aaagcccagc	tgccggcgcc	ccatttccct	ggcttcgcga	aagaccttga	420
accactgctc	ggtgctcagc	tccttgccct	gctcggcgaa	gtccagcggt	ttggaacagt	480
aggggcattg	cagcgggcaa	cgataggtca	gctccgcccag	caaccacagc	ggcaagccga	540
tcgctggctg	gtcaggcaag	ttcgatccaa	tgctctgcac	gggcgacctc	catgaactgc	600
tcgatgtcgt	caccgagttc	ggcacgtcgg	gaaactgggt	ggccagctcg	ccgatgatgg	660



ctgcgacata	ccgttaccgt	cgatcaggcc	cgccgatcaa	cgcaacgctt	gcgttgaact	720
tgatcatgcc	tttcaggaaa	aaaacaaaca	catgaccttt	gtgcgcccgg	ttcgtacttg	780
gaaagcgata	agccggggcc	gccaaccgaa				810

<210> 6

<211> 354

<212> DNA

<213> Pseudomonas sp.

<400> 6

gttactaaat	taaacaaaat	cgcacgcctc	gattctccga	gaaagctcat	tcagacgct	60
gtaatgatca	tttcggcatg	tgccaatggt	catccgggca	aacaccgttg	ctcaggcaat	120
accggccacc	ttcggcgctc	atcaggcgtc	gggtggcatc	gagcaattgc	ttgcgattca	180
atcctgcgat	cgcacgcgaa	agttgctcaa	ggtaatccga	cgggcggccg	gccagtttac	240
cctgccaaag	caattcggcc	gttgggcgca	gggcaagggt	tcgcttgtga	aactgggagg	300
cgaagtgcgc	gttgctgggt	cgagcaagggt	cgaatcgctc	acctgtcgga	tcag	354

09890306 10304

09/890306

Attorney's Docket No.: 13377-002001

JG18 Rsc'd PCT/PTO 27 JUL 2001

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Murali Nayudu et al.  
Serial No. : Unassigned  
Filed : Herewith  
Title : A METHOD OF CONTROLLING FUNGAL PATHOGENS, AND AGENTS  
USEFUL FOR SAME

**BOX PCT**

Commissioner for Patents  
Washington, D.C. 20231

**PRELIMINARY AMENDMENT**

Prior to examination, please amend the application as follows:

In the claims:

Amend claims 3-5, 7-8, 17-18, 27, 31-33, 39-40, 43, 45, 47, 51-52, 59-60, 62-63, and 65-70 as follows:

--3. (Amended) The method according to claim 1 wherein the fungal pathogen is *G. graminis* (take-all fungus).--

--4. (Amended) The method according to claim 1 wherein the fungal pathogen is *Botrytis fabae*.--

--5. (Amended) The method according to claim 1 wherein the sugar acid is selected from the group consisting of mannonic acid, gluconic acid, and galacturonic acid.--

CERTIFICATE OF MAILING BY FIRST CLASS MAIL

EL 48571298 SUS  
I hereby certify under 37 CFR §1.8(a) that this correspondence is being deposited with the United States Postal Service as first class mail with sufficient postage on the date indicated below and is addressed to the Commissioner for Patents, Washington, D.C. 20231.

Date of Deposit

Signature

Typed or Printed Name of Person Signing Certificate

July 27, 2001

Samantha Bell

Samantha Bell

--7. (Amended) The method according to claim 1 wherein the sugar acid is administered in pure or partially-purified form.--

--8. (Amended) The method according to claim 1 wherein the biocontrol agent is capable of producing an anti-fungal effective amount of the sugar acid when incubated in media containing an aldose substrate.--

--17. (Amended) The method according to claim 14 wherein the sugar acid is administered in pure or partially-purified form.--

--18. (Amended) The method according to claim 14 wherein the biocontrol agent is capable of producing an anti-fungal effective amount of the sugar acid when incubated in media containing an aldose substrate.--

--27. (Amended) The biocontrol agent according to claim 25 wherein the derivative has enhanced capacity compared to *Pseudomonas* strain AN5rif to colonize the rhizosphere of a plant.--

--31. (Amended) A phytoprotective composition for the treatment of a fungal infection of a plant comprising the biocontrol agent according to claim 24 in combination with a phytopathologically-acceptable diluent or wetting agent.--

--32. (Amended) The phytoprotective composition according to claim 28 wherein the wetting agent is a non-ionic detergent.--

--33. (Amended) The phytoprotective composition according to claim 28, wherein the fungal infection is an infection by a fungal pathogen selected from the group consisting of *Alternaria* spp.; *A. mellae*; *A. oligosporus*; *B. granulatus*; *B. cinerea*; *Botrytis fabae*; *C. purpurea*; *C. ribicola*; *E. purpurens*; *F. annosus*; *F. oxysporum*; *G. graminis* var. *tritici*; *G. cingulata*; *G. juniperi-virginianae*; *M. fructicola*; *P. alfalfae*; *P. infestans*; *P. sulphureus*;

03890306.10501

*Puccinia spp.*; *S. apiicola*; *Ustilago spp.*; *V. inaequalis*; and *V. dahliae*; and still more preferably, a fungal pathogen of monocotyledonous plants selected from the group consisting of *C. purpurea*; *G. graminis* var *tritici*; *Puccinia spp.*; and *Ustilago spp.*--

--39. (Amended) A composition for the treatment of a fungal infection in a human or other mammal comprising the biocontrol agent according to claim 24 in combination with one or more pharmaceutically-acceptable carriers or diluents.--

--40. (Amended) The composition according to claim 36 for the treatment of a condition selected from the group consisting of tinea pedis (athlete's foot), tinea cruris, tinea corporis (ringworm), candidiasis, onychia, paronychia, external genital candidiasis, candidal balanitis, pityriasis versicolor and jockey-strap itch.--

--43. (Amended) The method according to claim 41 wherein the aldose is selected from the group consisting of glucose, mannose and galactose.--

--45. (Amended) The method according to claim 41 wherein the culture conditions comprise growth on potato dextrose media or pontiac medium containing aldose substrate.--

--47. (Amended) The method according to claim 41 wherein the culture conditions comprise growth on potato dextrose media or pontiac medium followed by incubation in a concentrated solution of aldose substrate.--

--51. (Amended) The isolated nucleic acid molecule according to claim 48 comprising the nucleotide sequence of SEQ ID NO: 1.--

--52. (Amended) The isolated nucleic acid molecule according to claim 48 comprising the nucleotide sequence of the *Pseudomonas* genome contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622).--

--59. (Amended) The isolated nucleic acid molecule according to claim 53 comprising the nucleotide sequence of the *Pseudomonas* genome contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621).--

--60. (Amended) A method of producing a sugar acid comprising expressing the isolated nucleic acid molecule according to claim 48 in a cell, tissue or organism and culturing said cell, tissue or organism in the presence of an aldose substrate for a time and under conditions sufficient to produce a sugar acid.--

--62. (Amended) The method according to claim 60 further comprising extracting or purifying the sugar acid produced.--

--63. (Amended) The method according to claim 60 wherein the cell is a bacterial cell.--

--65. (Amended) The method according to claim 60 wherein the cell, tissue or organ is a plant cell, tissue, or organ.--

--66. (Amended) The method according to claim 60 further comprising expressing a nucleic acid molecule for a time and under conditions sufficient to produce PQQ in the cell, tissue or organ; wherein the nucleic acid molecule comprises a nucleotide sequence encoding one or more enzymes involved in the biosynthesis of PQQ, wherein said nucleotide sequence is selected from the group consisting of:

- (i) a nucleotide sequence having at least about 50 contiguous nucleotides of any one of SEQ ID NOs: 2 to 6 or a complementary sequence thereto;
- (ii) a nucleotide sequence having at least about 50 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621); and
- (iii) a nucleotide sequence that is degenerate to any one of SEQ ID NOs: 2 to 6 or the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession

TESEOT 90E05560

No. NM 00/09621).--

--67. (Amended) A method of enhancing the tolerance of a plant to infection by a fungal pathogen comprising expressing therein the isolated nucleic acid molecule according to claim 48, and optionally a second isolated nucleic acid molecule encoding one or more PQQ-biosynthesis enzymes, for a time and under conditions sufficient for a sugar acid to be produced by said plant, or by a cell, tissue or organ of said plant.--

--68. (Amended) The method according to claim 67 wherein the second isolated nucleic acid molecule comprises a nucleotide sequence encoding one or more enzymes involved in the biosynthesis of PQQ, wherein said nucleotide sequence is selected from the group consisting of:

- (i) a nucleotide sequence having at least about 50 contiguous nucleotides of any one of SEQ ID NOs: 2 to 6 or a complementary sequence thereto;
- (ii) a nucleotide sequence having at least about 50 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621); and
- (iii) a nucleotide sequence that is degenerate to any one of SEQ ID NOs: 2 to 6 or the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621).--

--69. (Amended) A transformed plant comprising the isolated nucleic acid molecule claim 48.--

--70. (Amended) A progeny plant, cell, tissue or organ of the plant according to claim 69, wherein said progeny, cell, tissue or organ comprises the isolated nucleic acid molecule; wherein the nucleic acid molecule comprises a nucleotide sequence which encodes one or more enzymes involved in the biosynthesis of a sugar acid, wherein said nucleotide sequence is selected from the group consisting of:

- (i) a nucleotide sequence which is at least about 50% identical to at least about 30 contiguous nucleotides of SEQ ID NO: 1 or a complementary sequence thereto;
- (ii) a nucleotide sequence which is at least about 50% identical to at least about 30 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622);
- (iii) a nucleotide sequence which is capable of hybridising under at least low stringency conditions to at least about 30 contiguous nucleotides of SEQ ID NO: 1 or a complementary sequence thereto;
- (vi) a nucleotide sequence which is capable of hybridising under at least low stringency conditions to at least about 30 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622); and
- (vii) a nucleotide sequence which is degenerate to SEQ ID NO: 1 or the *Pseudomonas* gene sequence contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622).--

Add claims 71 and 72 as follows:

--71. (New) A transformed plant comprising the isolated nucleic acid molecule claim

53.--

--72. (New) A progeny plant, cell, tissue or organ of the plant according to claim 69, wherein said progeny, cell, tissue or organ comprises the isolated nucleic acid molecule; wherein the nucleic acid molecule comprises a nucleotide sequence encoding one or more enzymes involved in the biosynthesis of PQQ, wherein said nucleotide sequence is selected from the group consisting of:

- (i) a nucleotide sequence having at least about 50 contiguous nucleotides of any one of SEQ ID NOs: 2 to 6 or a complementary sequence thereto;
- (ii) a nucleotide sequence having at least about 50 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession

Applicant : Murali Nayudu et al  
Serial No. :  
Filed :  
Page : 7

Attorney's Docket No.: 13377-002001

No. NM 00/09621); and

- (iii) a nucleotide sequence that is degenerate to any one of SEQ ID NOs: 2 to 6 or the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621).--

03690906-10604  
T06204 " 90E06B50



REMARKS

All amendments have been made to remove multiple dependency while conserving the claimed subject matter. More specifically, the limitations of claim 53 have been incorporated into claim 66 and 68 and the limitations of claim 48 have been incorporated into claim 70. Further, new claims 71 and 72 are subsets of original claims 69 and 70, respectively. Thus, no new matter has been introduced.

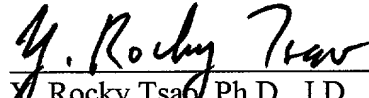
Attached is a marked-up version of the changes being made by the current amendment.

Claims 1-72 are now pending. Applicant submits that all of the claims are now in condition for examination, which action is requested. Please apply any charges to Deposit Account No. 06-1050.

Respectfully submitted,

Date: \_\_\_\_\_

7-27-01

  
Y. Rocky Tsao, Ph.D., J.D.  
Attorney for Applicants  
Reg. No. 34,053

Fish & Richardson P.C.  
225 Franklin Street  
Boston, MA 02110-2804  
Telephone: (617) 542-5070  
Facsimile: (617) 542-8906

**Version with markings to show changes made**

In the claims:

Claims 3-5, 7-8, 17-18, 27, 31-33, 39-40, 43, 45, 47, 51-52, 59-60, 62-63, and 65-70 have been amended as follows:

3. (Amended) The method according to claim 1 [or 2] wherein the fungal pathogen is *G. graminis* (take-all fungus).

4. (Amended) The method according to claim 1 [or 2] wherein the fungal pathogen is *Botrytis fabae*.

5. (Amended) The method according to [any one of claims 1 to 4] claim 1 wherein the sugar acid is selected from the group consisting of mannonic acid, gluconic acid, and galacturonic acid.

7. (Amended) The method according to [any one of claims 1 to 6] claim 1 wherein the sugar acid is administered in pure or partially-purified form.

8. (Amended) The method according to [any one of claims 1 to 6] claim 1 wherein the biocontrol agent is capable of producing an anti-fungal effective amount of the sugar acid when incubated in media containing an aldose substrate.

17. (Amended) The method according to [any one of claims 14 to 16] claim 14 wherein the sugar acid is administered in pure or partially-purified form.

18. (Amended) The method according to [any one of claims 14 to 16] claim 14 wherein the biocontrol agent is capable of producing an anti-fungal effective amount of the sugar acid when incubated in media containing an aldose substrate.

27. (Amended) The biocontrol agent according to claim 25 [or 26] wherein the derivative has enhanced capacity compared to *Pseudomonas* strain AN5rif to colonize the rhizosphere of a plant.

31. (Amended) A phytoprotective composition for the treatment of a fungal infection of a plant comprising the biocontrol agent according to [any one of claims 24 to 27] claim 24 in combination with a phytopathologically-acceptable diluent or wetting agent.

32. (Amended) The phytoprotective composition according to [any one of claims 28 to 31] claim 28 wherein the wetting agent is a non-ionic detergent.

33. (Amended) The phytoprotective composition according to [any one of claims 28 to 32] claim 28, wherein the fungal infection is an infection by a fungal pathogen selected from the group consisting of *Alternaria* spp.; *A. mellae*; *A. oligosporus*; *B. granulatus*; *B. cinerea*; *Botrytis fabae*; *C. purpurea*; *C. ribicola*; *E. purpurea*; *F. annosus*; *F. oxysporum*; *G. graminis* var. *tritici*; *G. cingulata*; *G. juniperi-virginianae*; *M. fructicola*; *P. alfalfae*; *P. infestans*; *P. sulphureus*; *Puccinia* spp.; *S. apiicola*; *Ustilago* spp.; *V. inaequalis*; and *V. dahliae*; and still more preferably, a fungal pathogen of monocotyledonous plants selected from the group consisting of *C. purpurea*; *G. graminis* var *tritici*; *Puccinia* spp.; and *Ustilago* spp..

39. (Amended) A composition for the treatment of a fungal infection in a human or other mammal comprising the biocontrol agent according to [any one of claims 24 to 26] claim 24 in combination with one or more pharmaceutically-acceptable carriers or diluents.

40. (Amended) The composition according to [any one of claims 36 to 39] claim 36 for the treatment of a condition selected from the group consisting of tinea pedis (athlete's foot), tinea cruris, tinea corporis (ringworm), candidiasis, onychia, paronychia, external genital candidiasis, candidal balanitis, pityriasis versicolor and jockey-strap itch.

0590306-102501

43. (Amended) The method according to claim 41 [or 42] wherein the aldose is selected from the group consisting of glucose, mannose and galactose.

45. (Amended) The method according to [any one of claims 41 to 44] claim 41 wherein the culture conditions comprise growth on potato dextrose media or pontiac medium containing aldose substrate.

47. (Amended) The method according to [any one of claims 41 to 44] claim 41 wherein the culture conditions comprise growth on potato dextrose media or pontiac medium followed by incubation in a concentrated solution of aldose substrate.

51. (Amended) The isolated nucleic acid molecule according to [any one of claims 48 to 50] claim 48 comprising the nucleotide sequence of SEQ ID NO: 1.

52. (Amended) The isolated nucleic acid molecule according to [any one of claims 48 to 51] claim 48 comprising the nucleotide sequence of the *Pseudomonas* genome contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622).

59. (Amended) The isolated nucleic acid molecule according to [any one of claims 53 to 58] claim 53 comprising the nucleotide sequence of the *Pseudomonas* genome contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621).

60. (Amended) A method of producing a sugar acid comprising expressing the isolated nucleic acid molecule according to [any one of claims 48 to 52] claim 48 in a cell, tissue or organism and culturing said cell, tissue or organism in the presence of an aldose substrate for a time and under conditions sufficient to produce a sugar acid.

62. (Amended) The method according to claim 60 [or 61] further comprising extracting or purifying the sugar acid produced.

105201 " 90E06860

65. (Amended) The method according to [any one of claims 60 to 62] claim 60 wherein the cell, tissue or organ is a plant cell, tissue, or organ.

(i) a nucleotide sequence having at least about 50 contiguous nucleotides of any one of SEQ ID NOs: 2 to 6 or a complementary sequence thereto;

(ii) a nucleotide sequence having at least about 50 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621); and

(iii) a nucleotide sequence that is degenerate to any one of SEQ ID NOs: 2 to 6 or the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621).

67. (Amended) A method of enhancing the tolerance of a plant to infection by a fungal pathogen comprising expressing therein the isolated nucleic acid molecule according to [any one of claims 48 to 52] claim 48, and optionally a second isolated nucleic acid molecule encoding one or more PQQ-biosynthesis enzymes, for a time and under conditions sufficient for a sugar acid to be produced by said plant, or by a cell, tissue or organ of said plant.

68. (Amended) The method according to claim 67 wherein the second isolated nucleic acid molecule [is the nucleic acid molecule according to any one of claims 53 to 59] comprises a nucleotide sequence encoding one or more enzymes involved in the biosynthesis of

PQQ, wherein said nucleotide sequence is selected from the group consisting of:

- (i) a nucleotide sequence having at least about 50 contiguous nucleotides of any one of SEQ ID NOs: 2 to 6 or a complementary sequence thereto;
- (ii) a nucleotide sequence having at least about 50 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621); and
- (iii) a nucleotide sequence that is degenerate to any one of SEQ ID NOs: 2 to 6 or the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621)..

69. (Amended) A transformed plant comprising the isolated nucleic acid molecule [according to any one of claims 48 to 59] claim 48.

70. (Amended) A progeny plant, cell, tissue or organ of the plant according to claim 69, wherein said progeny, cell, tissue or organ comprises the isolated nucleic acid molecule [according to any one of claims 48 to 59] ; wherein the nucleic acid molecule comprises a nucleotide sequence which encodes one or more enzymes involved in the biosynthesis of a sugar acid, wherein said nucleotide sequence is selected from the group consisting of:

- (i) a nucleotide sequence which is at least about 50% identical to at least about 30 contiguous nucleotides of SEQ ID NO: 1 or a complementary sequence thereto;
- (ii) a nucleotide sequence which is at least about 50% identical to at least about 30 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622);
- (iii) a nucleotide sequence which is capable of hybridising under at least low stringency conditions to at least about 30 contiguous nucleotides of SEQ ID NO: 1 or a complementary sequence thereto;
- (vi) a nucleotide sequence which is capable of hybridising under at least low stringency conditions to at least about 30 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622); and

Attorney's Docket No.: 13377-002001

**00000000000000000000000000000000**

23/PR 75

09/890306  
JC18 Rec'd PCT/PTO 27 JUL 2001

WO 00/44230

PCT/AU00/00046

- 1 -

**A METHOD OF CONTROLLING FUNGAL PATHOGENS, AND AGENTS**

**USEFUL FOR SAME**

**5 FIELD OF THE INVENTION**

5 The present invention relates generally to the use of a sugar acid to inhibit, retard or  
otherwise control the growth and/or viability of plant pathogens, such as, for example,  
those prokaryotic and eukaryotic organisms which infect or otherwise infest plants or  
parts of plants. In particular, the present invention relates to the use of a sugar acid  
10 selected from the group consisting of gluconic acid, mannonic acid, malic acid,  
ascorbic acid, glucaric acid, glutaric acid, glucuronic acid, galacturonic acid and  
galactonic acid to inhibit, retard or otherwise control the growth and/or viability of a  
plant pathogen, in particular a fungal pathogen. The invention further extends to the  
use of a sugar acid in the manufacture of a phytoprotective agent for the treatment of  
15 fungal infestations of plants. As disclosed herein, the sugar acid may be applied to a  
plant or plant part in crude or pure form, and, as a consequence, the invention further  
extends to a microorganism which is capable of producing a sugar acid when provided  
with an appropriate substrate, such as, for example, a species or sub-species of the  
genus *Pseudomonas* which is capable of metabolizing D-glucose and other carbon  
20 sources to a corresponding sugar acid. The present invention further provides  
nucleotide sequences of *Pseudomonas* sp. which encode and/or otherwise facilitate  
the synthesis of sugar acids in prokaryotic and eukaryotic organisms, in particular  
bacteria and/or plants. The present invention further contemplates transgenic plants  
and microorganisms which have been genetically engineered to produce sugar acids  
25 at levels sufficient to control the growth and/or viability of one or more plant pathogens.

**GENERAL**

This specification contains nucleotide sequence information prepared using the  
programme PatentIn Version 2.0, presented herein after the claims. Each nucleotide  
30 sequence is identified in the sequence listing by the numeric indicator <210> followed



- 2 -

by the sequence identifier (e.g. <210>1, <210>2, etc). The length, type of sequence (DNA, protein (PRT), etc) and source organism for each nucleotide sequence are indicated by information provided in the numeric indicator fields <211>, <212> and <213>, respectively. Nucleotide sequences referred to in the specification are defined  
5 by the term "SEQ ID NO:", followed by the sequence identifier (eg. SEQ ID NO: 1 refers to the sequence in the sequence listing designated as <400>1).

The designation of nucleotide residues referred to herein are those recommended by the IUPAC-IUB Biochemical Nomenclature Commission, wherein A represents  
10 Adenine, C represents Cytosine, G represents Guanine, T represents thymine, Y represents a pyrimidine residue, R represents a purine residue, M represents Adenine or Cytosine, K represents Guanine or Thymine, S represents Guanine or Cytosine, W represents Adenine or Thymine, H represents a nucleotide other than Guanine, B represents a nucleotide other than Adenine, V represents a nucleotide other than  
15 Thymine, D represents a nucleotide other than Cytosine and N represents any nucleotide residue.

Bibliographic details of the publications referred to in this specification are collected at the end of the description.

20

As used herein the term "derived from" shall be taken to indicate that a specified integer may be obtained from a particular source albeit not necessarily directly from that source.

25 Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated step or element or integer or group of steps or elements or integers but not the exclusion of any other step or element or integer or group of elements or integers.

30

Those skilled in the art will appreciate that the invention described herein is susceptible

- 3 -

to variations and modifications other than those specifically described. It is to be understood that the invention includes all such variations and modifications. The invention also includes all of the steps, features, compositions and compounds referred to or indicated in this specification, individually or collectively, and any and all  
5 combinations or any two or more of said steps or features.

The present invention is not to be limited in scope by the specific embodiments described herein, which are intended for the purposes of exemplification only. Functionally-equivalent products, compositions and methods are clearly within the  
10 scope of the invention, as described herein.

## BACKGROUND OF THE INVENTION

Pathogenic infections, in particular fungal infections, of animals (including humans and agricultural and domestic animals), and plants, (in particular, agriculturally-significant  
15 plants) produce significant losses in productive capacity worldwide.

True fungal pathogens may be classified into at least three major classes, the Phycomycetes, the Ascomycetes, and the Basidiomycetes.

20 With particular regard to fungal pathogens which infect humans and other mammals, over 40 species are known which attack epithelial tissues (eg. hair, skin, and nails), causing diseases and discomforts of an annoying nature, such as, for example, tinea pedis (athlete's foot), tinea cruris, tinea corporis (ringworm) due to infection by the dermatophytes *Trichophyton rubrum*, *T. mentagrophytes*, *Epidermophyton floccosum*,  
25 and *Microsporum canis*; candidiasis due to *Candida albicans*, including cutaneous candidiasis (thrush), onychia, paronychia, external genital candidiasis, candidal balanitis; pityriasis versicolor due to *Pityrosporum orbiculare* (*Malassezia furfur*); and jockey-strap itch. Additionally, certain species of fungi infect sub-cutaneous tissues, including those of major internal organs, to produce serious systemic diseases,  
30 including blastomycosis, coccidiomycosis, histoplasmosis, and sporotrichosis. These more serious fungal infections are generally soil-borne, easily aerosolized, spread by

- 4 -

air currents, and, as a consequence, contracted by inhalation. The fungal pathogens are mostly dimorphic, occurring as a mycelium in the non-pathogenic state, which bears infectious spores.

- 5 Many more fungal pathogens produce a variety of diseases in plants, wherein different species of fungi tend invade particular species, and particular tissues, of plants. Crop damage from fungal infection accounts for many millions of dollars in lost profits annually. The Basidiomycetes are of particular importance in agriculture, and include the rust fungi, such as, for example, *Puccinia* spp., *Cronartium ribicola*, and
- 10 *Gymnosporangium juniperi-virginianae*; the smut fungi, such as, for example, *Ustilago* spp., which infect corn and oats, amongst others, causing up to 30% losses annually. Additionally, take-all disease, which is caused by infection of wheat plants by the fungal pathogen *Gaeumannomyces graminis* var *tritici* (or commonly known as the "take-all" fungus) is the most significant root disease of wheat around the world and
- 15 currently leads to 10% loss of the annual wheat crop in Australia (Murray and Brown, 1987). Other important fungal diseases in plants include crown wart of alfalfa disease, which is caused by *Physoderma alfalfae*; bitter rot of apple disease, caused by *Glomerella cingulata*; apple rust, caused by *Gymnosporangium juniperi-virginianae*; apple scab, caused by *Venturia inaequalis*; banana wilt, caused by *Fusarium*
- 20 *oxysporum* f. *cubense*; loose smut of barley, caused by *Ustilago nuda* Rostr.; early and late blight in celery, caused by *Septoria apiicola*; *Fusarium* yellow in celery, caused by *Fusarium oxysporum* f. *apii* Snyder Hansen; ergot in grain crops, and grasses, caused by *Claviceps purpurea*; stem rusts, caused by *Puccinia* spp., in particular *P. graminis*; late blight in potato, caused by *Phytophthora infestans*; and citrus root rot diseases
- 25 caused by *Armillaria mellea*. However, this list is not exhaustive.

Methods for the prophylactic and/or therapeutic treatment of fungal and bacterial infections in animals and plants generally involve the application of anti-fungal and anti-bacterial chemicals; the use of biocontrol agents; and, more recently, and

30 particularly in the case of plants, the genetic engineering of crops to express disease tolerance or disease-resistance genes therein.

*Fungicidal and fungistatic chemical compounds:*

Anti-fungal chemicals are varied in composition and designed to either eradicate the fungal pathogen, such as, for example, by acting against the fungal spores, or alternatively, to prevent the germination of fungal spores once they have infected their host. However, most chemicals do not fall exclusively into a single category. For example, elemental sulfur has been used to protect apple crops against apple scab, however the same chemical is eradivative when used against a rust fungus.

10 A wide variety of pyridine compounds and derivatives thereof having varying, and often multiple, action, are used in agrochemicals and pharmaceuticals against fungal pathogens, such as, for example, 3-(2-methylpiperidino) propyl-3,4-dichlorobenzoate; cephalosporin C; cephalirin sodium; pyriithione zinc (i.e. 2-mercaptopyridine N-oxide); and 2-sulfanylamidopyridine.

15

Many of the compounds used commonly to treat fungal infections in humans interfere with fungal sterol biosynthesis. For example, the imidazoles (including bifonazole [i.e. 1-( $\alpha$ -biphenyl-4-ylbenzyl)-imidazole], clotrimazole, econazole nitrate, and miconazole nitrate [i.e. 1-[2,4-dichloro- $\beta$ -(2, 4-dichlorobenzyloxy)phenethyl] imidazole nitrate]),

20 which have broad spectrum antifungal activity against dermatophytes and yeasts alter fungal cell membranes by interfering with ergosterol production. The allylamines, such as, for example, terbafine hydrochloride ( $C_{21}H_{25}N \cdot HCl$ ), are also of use in the treatment of infections by dermatophytes, also interfere with ergosterol production. Terbafine also results in the accumulation of squalene in the fungus, resulting in fungal cell death. Amorolfine hydrochloride (*cis*-4-[(*RS*)-3-[4-(1,1-dimethylpropyl) phenyl]-2-methyl propyl]-2,6-dimethyl morpholine hydrochloride) is in a relatively new class of compounds active against a wide range of yeasts, dermatophytes, moulds, and dimorphic fungi. The fungicidal /fungistatic effect of amorolfine hydrochloride is based upon modification to the fungal cell membranewhich is produced by reducing the ergosterol content and increasing the levels of sterically-nonplanar sterols in the fungal cell membrane.

- 6 -

Agricultural fungicides and their modes of application are reviewed in detail by Gennaro *et al.* (1990), and Kirk-Othmer (1980). These compounds are generally of the class of polysulfides; heavy-metal fungicides; and the organic fungicides, such as, for example, the quinones (in particular, chlroanil and dichlone), organic sulfur-  
5 containing compounds (in particular, the dithiocarbamates), imidazolines and guanines (in particular heptadecyl-2-imidozolinium acetate; and dodecylguanidium acetate), trichloromethylthiocarboximides [in particular, N-trichloromethylthio)-4-cyclohexene-1,2-dicarboximide (captan); and N-(trichloromethylthio) phthalimide (folpet)], the chlorinated and/or nitrated benzene derivatives [ in particular, 2,3,5,6-  
10 tetrachloronitrobenzene; pentachloronitrobenzene (PCNB); 1,3,5- trichloro-2,4,6-trinitrobenzene; 1,2,4- trichloro-3,5-dinitrobenzene; hexachlorobenzene; 2,6-dichloro-4-nitroaniline (dichloran); 1,4-dichloro-2,5-dimethoxybenzene; and tetrachloroisophthalonitrile (chlorothalonil)]. Various other compounds having systemic anti-fungal activity in agricultural applications (i.e. systemic fungicides) include the  
15 oxathiins (in particular, carboxin); benzimidazoles [in particular, methyl-2-benzimidazolylicarbamate (MBC)]; pyrimidines [in particular, 5-butyl-2-dimethylamino-6-methyl-4(1*H*)-pyrimidinone (dimethirimol); the 2-ethylamino analogue, ethirimol; and  $\alpha$ -(2,4-dichlorophenyl)- $\alpha$ -phenyl-5-pyrimidinemethanol (triarimol)]. The antibiotics, including cycloheximide, bastocidin S, kasugamycin, and the polyoxins, are also used  
20 extensively.

In most cases the mode of action of known agricultural anti-fungal compounds remains elusive, and, as with antifungal compounds that are effective against fungal pathogens of humans, many compounds alter fungal cell membrane metabolism. For example,  
25 triarimol and related compounds inhibit steps in sterol biosynthesis. However, carboxin is known to block mitochondrial respiration by inhibiting succinate dehydrogenase, whilst the benzimidazoles disrupt cell structures, such as those required for mitosis.

- 7 -

*Anti-fungal biocontrol agents:*

Biological control protection refers to the introduction of living organisms, such as, for example, bacteria, fungi, and insects, to control plant pathogens. Three properties

5 make biocontrol agents a desirable option in plant protection against fungal pathogens.

First, biocontrol agents are generally natural products and, as such, are less likely to have a detrimental effect on the environment than synthetic chemicals. Secondly, biocontrol agents are relatively inexpensive compared to synthetic chemicals. Third, biocontrol agents represent an inexhaustible source of protectant, because

10 microorganisms can be maintained in culture, and expanded rapidly and inexpensively.

Biocontrol agents either act by occupying the site of infection of a pathogen, and competing with the pathogen for nutrients derived from the plant, or alternatively, the biocontrol agent produces fungicidal and/or fungistatic compounds that specifically

15 attack the fungal pathogen. Significant factors important in biological control (such as colonization, antibiosis, siderophore production etc.) have been identified, however the influence of these factors varies with environmental conditions so it is difficult to assign a universal mechanism of action to biocontrol agents (Weller, 1988).

20 The universal feature of all biocontrol agents is their capacity to rapidly multiply in the cells and tissues that are infected by the pathogenic agent and to form an association therewith, a process which has been termed "colonization" (Suslow, 1982). In fact, Weller (1988) identified three factors as being responsible for the suppressive nature of various bacteria against fungi: colonization of the root; the production of fungicides  
25 and/or fungistatic compounds, including antibiotics, HCN (Fravel, 1988), or hydrogen peroxide (Wu et al, 1995; US Patent No. 5, 516, 671), amongst others; and the production of fluorescent siderophores, or high-affinity iron-transport agents. In this regard, the different colonization host range shown by biocontrol bacteria (Weller, 1988) suggests there is some host specificity in colonization, and that a number of  
30 factors are involved. As will be known to those skilled in the art, there is also host-specificity in the action of fungicides, and this might explain why some strains are

- 8 -

ineffective against certain pathogens (Schroth and Hancock, 1981). Additionally, not all biocontrol agents act by producing fungicides or fungistatic compounds (Kraus and Loper, 1992).

- 5 There are a large number of systems in which biocontrol is effective (Weller, 1988). In general, biocontrol agents have been shown to have a beneficial effect to the plant under controlled conditions in the glasshouse and in a large number of cases in the field (Baker and Cook, 1974) . There are currently numerous biocontrol agents used by farmers for disease control (Schroth and Hancock, 1981), showing that it is  
10 effective and viable as a method to control plant diseases in the field.

For example, *Sclerotinia* rot, caused by the fungi *Sclerotinia sclerotiorum*, *Sclerotinia minor*, and *Sclerotinia trifoliorum*, is one of the most destructive diseases of plants, affecting over 380 ornamentals (e.g. aster, begonia, calendula, chrysanthemum,  
15 fuchsia, gerbera, lupin, pelargonium, and petunia), field crops (e.g. alfalfa, canola, dry bean, hemp, lentil, oilseed rape, peanut, potato, red clover, safflower, soybean, sunflower, sweetclover, and tobacco), vegetables and fruits (e.g. artichoke, asparagus, avocado, bean, broccoli, cabbage, carrot, celery, chickpea, chicory, cucumber, eggplant, endive, fennel, kiwi fruit, leek, lettuce, parsley, pea, pepper (chilli, red or  
20 sweet), snap bean, tomato, watermelon, garlic and onion) and herbs (e.g. coriander, chives, dill, fennel, and wintercress). A biological plant-protection agent, containing as an active ingredient contains viable spores of the soil fungus *Coniothyrium minitans*, has been developed recently which has specific antagonistic action against the survival structures (sclerotia) of these fungal pathogenic agents. Once applied and  
25 incorporated into the soil, *C. minitans* germinates and attacks the sclerotia (resting survival structures) of the pathogens within the soil, thereby reducing recurrences of the disease in the soil.

In the case of take-all disease in wheat, *Pseudomonas* sp., have been identified which  
30 produce a low molecular weight siderophore, sometimes fluorescent, capable of complexing and actively-transporting iron inside the cell, to produce an iron deficiency

- 9 -

in the soil (Buyer and Leong, 1986; Leong, 1986), thereby effectively starving the fungal pathogen of soil-derived iron necessary for germination and growth. However, siderophore production is now thought only to be important in the biocontrol of take-all disease in alkaline soils which have low iron concentration, wherein iron may be a limiting nutrient for the fungus (Kloepper *et al.*, 1980). Moreover, Fravel, (1988); Hamdan *et al.* (1991); and Thomashow *et al.*, (1990), have suggested that the dominant important factor in disease suppression is the production of fungicides and/or fungistatic compounds by *Pseudomonas sp.*, in particular phenazine -1-carboxylic acid (Thomashow *et al.*, 1993); and 2,4-diacetylphloroglucinol, a normal intermediary in a pathway in bacteria which inhibits a range of fungal pathogens, and is found in a wide range of Pseudomonads (Keel *et al.*, 1992; 1996). Phenazine has been extensively characterised in take-all biological control protection, however the effectiveness of 2,4-diacetylphloroglucinol against take-all has only been partially characterised (Raaijmakers and Weller, 1998). *Pseudomonas fluorescens* strain CHA0 has been also extensively studied and shown to produce an effective amount of 2, 4-diacetylphloroglucinol for the suppression of black rot disease of tobacco and take-all disease of wheat (Laville *et al.*, 1992).

Additionally, the isolated *Pseudomonas* strain AN5, has been shown to have a wide host range in so far as it is able to colonize the roots of a number of plant species, and is an effective biocontrol agent against take-all disease in agar plate assays, pot experiments, and in field trials (Nayudu *et al.* 1994b). Those authors concurred with Thomashow *et al.*, (1993) in concluding that the dominant effects of this bacterium appeared to reside in the production of fungicides and/or fungistatic compounds, rather than in the production of siderophores.

Although other biocontrol agents have been tested for their ability to control take-all disease, such as, for example, non-pathogenic strains of *G. graminis* var. *graminis* (Wong *et al.*, 1996), they are not a feasible method for large scale control of take-all as there is no current technology available to grow such fungi on a large scale. The cost of producing such a fungal agent and to apply same in the field is prohibitively



- 10 -

high compared to bacterial biocontrol agents.

*Genetically-manipulated plants expressing disease resistance or tolerance:*

In certain instances of disease in plants, genes which encode particular enzymes that  
5 are involved in the production of anti-fungal (i.e. fungicidal and/or fungistatic)  
compounds have been identified and expressed in plants to introduce tolerance or  
resistance thereto. In such cases, there is a requirement for the plant to be capable of  
expressing the introduced gene(s) and to produce the anti-fungal product from either  
endogenous plant metabolites, or alternatively or in addition, from exogenous  
10 substrates. As will be known to those skilled in the art, once synthesized, the anti-  
fungal compound must be capable of diffusion to an appropriate site of action, or  
actively transported, to exert its action against the invading pathogen.

One example of such protection is the expression of a gene encoding the *Aspergillus*  
15 *niger* or *Talaromyces flavus* glucose oxidase enzymes (EC 1.1.3.4) to control  
*Phytophthora infestans*, or *Veticillium dahliae* (Murray *et al.*, 1997; Stosz *et al.*, 1996;  
Wu *et al.*, 1995; US Patent No. 5,516,671) in plants. The efficacy of this approach was  
based upon the involvement of hydrogen peroxide in plant defense responses in  
incompatible plant-pathogen interactions, wherein it may activate the production of  
20 phytoalexins and other cellular protectants, such as, for example, salicylic acid and  
glutathione-S-transferases; induces cross-linking of hydroxyproline-rich glycoproteins  
(HPGP); and is involved in triggering hypersensitive cell death in response to pathogen  
invasion. Additionally, hydrogen peroxide is a product of the enzymic action of glucose  
oxidase, which catalyzes the oxidation of glucose to  $\delta$ -gluconolactone and hydrogen  
25 peroxide, and, as a consequence, the expression of glucose oxidase in plants was  
considered a suitable means for producing hydrogen peroxide as an anti-fungal agent.  
The attractiveness of this approach arose, in part, from the knowledge that the glucose  
oxidase gene of *Penicillium dangearii*, is involved in the effective biocontrol of *V.*  
*dahliae* by this organism (Kim *et al.*, 1988, 1990; US Patent No. 5, 516, 671).

30

Plants expressing a range of leucine-rich repeat proteins that comprise nucleotide

- 11 -

binding sites have also been described as providing improved protection against various diseases in plants, including rust fungi (see, for example, International Patent Application No. PCT/AU95/00240).

## 5 SUMMARY OF THE INVENTION

In work leading up to the present invention, the present inventors sought to identify an environmentally-acceptable means for the treatment of a wide range of fungal pathogens in plants and animals. The inventors identified the anti-fungal component produced by *Pseudomonas* strain AN5 as a sugar acid, and have determined the  
10 biochemical and genetic pathway for its production. The identification of this particular anti-fungal agent, and the cloning of the genetic sequences required for the biosynthesis of the antifungal agent enables the development of strategies for the control of a wide range of fungal pathogens in plants and animals.

15 Accordingly, one aspect of the present invention is directed to a method of prophylactic or therapeutic treatment of infection by a fungal pathogen in an animal or plant comprising administering an effective amount of a sugar acid thereto for a time and under conditions sufficient to inhibit or prevent fungal growth or reproduction. In an alternative embodiment of the invention, a biocontrol agent which is capable of  
20 producing an anti-fungal effective amount of a sugar acid in the presence of an aldose substrate is administered tot the plant of animal to inhibit or prevent fungal growth or reproduction.

A second aspect of the invention provides a method of increasing the post-harvest  
25 storage of a plant product comprising applying thereto an effective amount of a sugar acid thereto for a time and under conditions sufficient to inhibit or prevent fungal growth or reproduction. In an alternative embodiment of the invention, a biocontrol agent which is capable of producing an anti-fungal effective amount of a sugar acid in the presence of an aldose substrate is applied to the plant product to inhibit or prevent  
30 fungal growth or reproduction. This aspect of the invention applies to any plant product, in particular those edible products intended for human or animal consumption,

- 12 -

which are susceptible to rapid degradation due to fungal infection, such as, for example, fruit and vegetables, including tomatoes, apples, pears, citrus fruits, grapes, and berries, amongst others.

- 5 A third aspect of the invention provides a biocontrol agent for the treatment of a fungal infection in a plant or animal, wherein said agent comprises an isolated bacterial cell which is capable of producing a sugar acid when cultured in the presence of a carbon source comprising an aldose, and wherein said biocontrol agent is further capable of colonising the infection site. In a particularly preferred embodiment, the biocontrol  
10 agent consists of an isolate of *Pseudomonas* sp. having the characteristics of *Pseudomonas* strain AN5 rif (AGAL Accession No. NM 00/09624).

A fourth aspect of the invention provides a phytoprotective composition for the treatment of a fungal infection of a plant comprising an effective amount of a sugar  
15 acid in combination with a phytopathologically-acceptable diluent or wetting agent. The phytoprotective composition may also include a biocontrol agent which produces the sugar acid in the presence of an appropriate aldose substrate by virtue of the expression of a PQQ-dependent sugar oxidase enzyme therein.

- 20 A fifth aspect of the invention provides a composition for the treatment of a fungal infection in a human or other mammal comprising an effective amount of a sugar acid in combination with one or more pharmaceutically-acceptable carriers or diluents. As with other compositions described herein, those compositions for animal use may comprise a biocontrol agent which expresses a PQQ-dependent sugar oxidase  
25 enzyme.

The active sugar acid and/or biocontrol agent, and compositions comprising same, as described herein, can be produced by any means known to those skilled in the art. Additionally, certain sugar acids, including gluconic acid, are readily available to the  
30 public from any one of a number of sources. However, in one embodiment, the present invention clearly extends to a method of producing a sugar acid comprising introducing

- 13 -

an isolated nucleic acid molecule which encodes a PQQ-dependent sugar acid biosynthetic enzyme to an organism and culturing said organism in the presence of an aldose substrate for a time and under conditions sufficient to produce a sugar acid. Preferably, the sugar acid is subsequently extracted from the organism. More  
5 preferably, the sugar acid is partially or substantially purified from the organism or an extract thereof.

Still another aspect of the present invention provides an isolated nucleic acid molecule comprising a nucleotide sequence which encodes one or more enzymes involved in  
10 the biosynthesis of a sugar acid or is complementary to said nucleotide sequence. Preferably, the nucleotide sequence of the invention encodes a sugar oxidase enzyme.

It will be evident from the foregoing discussion that not all cells produce PQQ as a cofactor, and, as a consequence, to produce a sugar acid in accordance with the  
15 inventive concept, it may be necessary in certain circumstances to express the enzymes required for PQQ biosynthesis, in addition to those gene(s) encoding the sugar oxidase enzyme. The present inventors have identified the PQQ operon of *Pseudomonas* strain AN5, comprising the genes the pqqA, pqqB, pqqC, pqqD, pqqE, and pqqF, which are involved in the production of PQQ. Accordingly, the present  
20 invention further provides an isolated nucleic acid molecule which comprises a nucleotide sequence encoding one or more polypeptides involved in the biosynthesis of PQQ.

A still further aspect of the invention provides a method of enhancing the tolerance of  
25 a plant to infection by a fungal pathogen comprising expressing therein a first isolated nucleic acid molecule encoding a sugar oxidase, and optionally a second isolated nucleic acid molecule encoding one or more PQQ-biosynthesis enzymes for a time and under conditions sufficient for a sugar acid to be produced by said plant, or by a cell, tissue or organ of said plant.

- 14 -

**BRIEF DESCRIPTION OF THE FIGURES**

**Figure 1** is a copy of a photographic representation of a thin layer chromatogram (TLC) of an agar overlay assay showing the biological activity of the anti-take-all compound from crude extract of *Pseudomonas* strain AN5. **Panel A** shows a TLC performed using a solvent comprising 10% (w/v) methanol in Chloroform. **Panel B** shows a TLC performed using a solvent comprising 30% (w/v) methanol in chloroform. **Panel C** shows a TLC performed using a solvent comprising 50% (w/v) methanol in chloroform. The take-all fungus was inoculated onto the top of the TLC plate in a potato dextrose overlay agar and has the ability to grow well. An inhibition zone, indicated by the arrow, corresponds to the location of an anti-fungal agent of *Pseudomonas* strain AN5 against take-all. This anti-fungal agent is at the origin and does not migrate in the presence of any of the solvents tested.

**Figure 2A** is a copy of a photographic representation of silica gel 60 F<sub>254</sub> TLC plates using a solvent system comprising *n*-propanol:ethyl acetate:water [5:2:3 (v/v)], showing the separation of compounds in crude extracts of *Pseudomonas* strain AN5 (panel a) and the mutant strain AN5-MN1 (panel b). The data indicate differences in the simple sugars produced by the mutant strain AN5-MN1, compared to *Pseudomonas* strain AN5.

**Figure 2B** is a copy of a photographic representation of the TLC plates of Figure 2A in an agar overlay assay, showing the biological activity of a compound produced by *Pseudomonas* strain AN5 (panel a), but not the mutant strain AN5-MN1 (panel b), against the take-all fungus, as evidenced by the arrow (inhibition zone). The solvent conditions are the same as shown in Figure 2A.

**Figure 3A** is a copy of a photographic representation of a silica gel 60 F<sub>254</sub> TLC plate using a solvent system comprising *n*-propanol:ethyl acetate:water [5:2:3 (v/v)], showing silica column fractions of *Pseudomonas* strain AN5. Numbering at the bottom of each lane indicates the fraction number collected from the silica column; and **C** indicates a crude extract of *Pseudomonas* strain AN5, which was used as starting material for the

- 15 -

silica column.

**Figure 3B** is a copy of a photographic representation of a PDA plate inoculated with take-all fungus, showing the biological activity of silica column fractions 17 to 20 shown in Figure 3A against the take-all fungus. Numbering corresponds to the silica column fraction number. The zone of clearing indicates inhibition of fungal growth, compared to the white patches where the fungus grows. Data indicate that fractions 17 to 20 are active against take-all fungus, and that fractions 19 and 20 contain the highest activity.

- 10 **Figure 4** is a copy of a photographic representation of a PDA plate in an agar overlay bioassay, showing the activity against take-all fungus of silica column fractions 17 to 20 of *Pseudomonas* strain AN5, following their re-chromatography on TLC as described in the legend to Figure 3A. The active fractions were eluted in four samples (based on R<sub>f</sub> value), numbered 1-4. Only fraction 3 (R<sub>f</sub> value 0.75) was active against
- 15 take-all fungus, as evidenced by the inhibition zone.

**Figure 5A** is a copy of a graphical representation of a <sup>1</sup>H NMR spectrum of the active fraction purified by silica column and TLC as indicated in the legends to Figures 3A and 4. Numbering on the x-axis indicates ppm.

20

**Figure 5B** is a copy of a graphical representation of a <sup>13</sup>C NMR spectrum of the active fraction purified by silica column and TLC as indicated in the legends to Figures 3A and 4. Numbering on the x-axis indicates ppm.

- 25 **Figure 5C** is a copy of a graphical representation of mass spectrum data of the active fraction of *Pseudomonas* strain AN5 against take-all fungus which was purified by silica column as indicated in the legends to Figure 3A and Figure 4. *Pseudomonas* strain AN5 was cultured with glucose as the sole carbon source. **Top panel:** data show abundance of each fragment as a function of mass/charge. **Lower panel:** data show
- 30 abundance of each fragment as a function of elution time (min). The arrow indicates the position of gluconolactone.

- 16 -

**Figure 5D** is a copy of a graphical representation of mass spectrum data of the active fraction of *Pseudomonas* strain AN5 against take-all fungus which was purified by silica column as indicated in the legend to Figure 4. *Pseudomonas* strain AN5 was cultured with glucose as the sole carbon source. **Top panel:** data show abundance of each fragment as a function of mass/charge. **Lower panel:** data show abundance of each fragment as a function of elution time (min). The arrow indicates the position of gluconic acid.

**Figure 6A** is a copy of a photographic representation of a PDA plate inoculated with *Pseudomonas* strain AN5, showing the biological activity of different amounts of pure gluconic acid (Sigma Chemical Company Pty. Ltd.) against take-all using an agar overlay bioassay. Numbering indicates the amount of sugar acid used, as follows: (1) 25mg; (2) 15mg; (3) 12.5mg; and (4) 7.5mg. Data indicate that there is a positive correlation between the amount of gluconic acid used and the size of the inhibition zone (cleared region), which inhibition zone is indicative of activity against take-all fungus.

**Figure 6B** is a copy of a photographic representation of a PDA plate inoculated with *Pseudomonas* strain AN5, showing the biological activities of different purified sugar acids (Sigma Chemical Company Pty. Ltd.) against the take-all fungus, using an agar overlay bioassay. The amount of sugar acid used was 12.5mg in each case. Numbering indicates the sugar acid used, as follows: (1) malic acid; (2) ascorbic acid; (3) glutaric acid; and (4) glucuronic acid. All four sugar acids produce strong inhibition zones (cleared regions), indicative of activity against the take-all fungus.

25

**Figure 7** is a black and white copy of a colour photographic representation of bacterial plates containing King's B media and inoculated with *Pseudomonas* strain AN5 (panel a), or *Pseudomonas fluorescens* Pf-5 (panel b). Data indicate that *Pseudomonas fluorescens* Pf-5 produces 2,4-diacetylphloroglucinol, by virtue of the darker appearance of this plate (which, in the original colour plate, is a red colour), compared to the whitened appearance of the plate in panel a. In contrast, *Pseudomonas* strain

30

AN5 does not produce detectable levels of 2,4-diacetylphloroglucinol in this assay. The original colour photographic representation is available on request.

**Figure 8** is a copy of a graphical representation of the  $^1\text{H}$  NMR spectrum of phenazine-5 1-carboxylic acid. Numbering on the x-axis indicates ppm.

**Figure 9A** is a copy of a graphical representation of  $^1\text{H}$  NMR of a crude extract of *Pseudomonas fluorescens* Pf-5 from malt agar. Numbering on the x-axis indicates ppm.

**Figure 9B** is a copy of a graphical representation of  $^1\text{H}$  NMR of a crude extract of *Pseudomonas* strain AN5 from malt agar. Numbering on the x-axis indicates ppm.

**Figure 10A** is a black and white copy of a colour photographic representation of three 15 PDA plates inoculated with *Pseudomonas* strain AN5 (panels a and b) or the mutant strain AN5-MN1 (panel c). In panels b and c, the indicator dye bromocresol purple was added to the growth medium, and the yellow colour in panel b of the original photographic representation (darker grey colour over a light grey background in the black and white copy) is indicative of an acidification of the medium by 20 *Pseudomonas* strain AN5. In panel c, the purple colour of the original photographic representation (very dark grey colour over a lighter grey background in the black and white copy) is indicative of an alkalinisation of the medium by *Pseudomonas* strain AN5-MN1. The original colour photographic representation is available on request.

**Figure 10B** is a black and white copy of a colour photographic representation of a 25 PDA plate containing the indicator dye bromocresol purple and inoculated with the take-all fungus. In the original photograph, the take-all fungus is shown as a black central zone, surrounded by a yellow zone of growth, and there is a purple zone around the take-all fungus, suggesting it is releasing compounds which increase pH 30 of the media. In the black and white copy, the take-all fungus is shown as a black central zone, surrounded by a light grey zone, and the purple zone around the take-all



- 18 -

fungus is represented by a darker grey zone towards the edges of the plate. The original colour photographic representation is available on request.

**Figure 11A** is a copy of a graphical representation of mass spectrum data of the active fraction of *Pseudomonas* strain AN5 against take-all fungus which was purified by silica column as indicated in the legend to Figure 3A. *Pseudomonas* strain AN5 was cultured with galactose as the sole carbon source. **Top panel:** data show abundance of each fragment as a function of mass/charge. **Lower panel:** data show abundance of each fragment as a function of elution time (min). The arrow indicates the position of galactonolactone.

**Figure 11B** is a copy of a graphical representation of mass spectrum data of the active fraction of *Pseudomonas* strain AN5 against take-all fungus which was purified by silica column as indicated in the legend to Figure 3A. *Pseudomonas* strain AN5 was cultured with galactose as the sole carbon source. **Top panel:** data show abundance of each fragment as a function of mass/charge. **Lower panel:** data show abundance of each fragment as a function of elution time (min). The arrow indicates the position of galactonic acid.

**Figure 12A** is a copy of a graphical representation of mass spectrum data of the active fraction of *Pseudomonas* strain AN5 against take-all fungus which was purified by silica column as indicated in the legend to Figure 3A. *Pseudomonas* strain AN5 was cultured with mannose as the sole carbon source. **Top panel:** data show abundance of each fragment as a function of mass/charge. **Lower panel:** data show abundance of each fragment as a function of elution time (min). The arrow indicates the position of mannono-1,4-lactone.

**Figure 12B** is a copy of a graphical representation of mass spectrum data of the active fraction of *Pseudomonas* strain AN5 against take-all fungus which was purified by silica column as indicated in the legend to Figure 3A. *Pseudomonas* strain AN5 was cultured with mannose as the sole carbon source. **Top panel:** data show abundance

- 19 -

of each fragment as a function of mass/charge. **Lower panel:** data show abundance of each fragment as a function of elution time (min). The arrow indicates the position of mannonic acid.

5 **Figure 13** is a copy of a schematic representation showing the aligned PQQ operons of *Klebsiella pneumoniae*, *Pseudomonas fluorescens* strain CHAO, *Acinetobacter calcoaceticus*, and *Pseudomonas* strain AN5, showing the locations of the pqqA, pqqB, pqqC, pqqD, and pqqE genes within the operon. Each gene is represented by a filled box, with the appropriate gene designation below.

10

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS.

The present invention is directed to a method of prophylactic or therapeutic treatment of infection by a fungal pathogen in an animal or plant or a cell, tissue or organ thereof, comprising administering an effective amount of a sugar acid thereto for a time and  
15 under conditions sufficient to inhibit or prevent fungal growth or reproduction.

By "fungal pathogen" is meant any fungus or yeast which is capable of infecting a plant or animal, including a human, in a manner so as to reduce productivity or health of said plant or animal, or to cause disease, morbidity or mortality therein. In the present  
20 context, the term "fungal pathogen" further includes any of the true fungi or yeasts which infect plants or animals.

The present invention is further useful in the delay or prevention of food spoilage due to infection of fungal pathogens, particularly in the case of plant products (i.e. fruits,  
25 and vegetables), in which case, the sugar acid or composition comprising same may be sprayed directly onto the produce to partially or completely inhibit fungal growth under standard storage conditions, thereby increasing the post-harvest life of produce.

In a preferred embodiment, the present invention is directed to the prophylactic or  
30 therapeutic treatment of infection by a fungal pathogen selected from the group consisting of: *Alternaria spp.*; *Armillaria melleae*; *Arthrobotrys oligosporus*; *Boletus*

- 20 -

*granulatus; Botritis cinerea; Botrytis fabae; Candida albicans; Claviceps purpurea; Cronartium ribicola; Epicoccum purpureascens; Epidermophyton floccosum; Fomes annosus; Fusarium oxysporum; Gaeumannomyces graminis var. tritici; Glomerella cingulata; Gymnosporangium juniperi-virginianae; Microsporum canis; Monilinia fructicola; Physoderma alfalfae; Phytophthora infestans; Pityrosporum orbiculare (Malassezia furfur); Polyporus sulphureus; Puccinia spp.; Saccharomyces cerevisiae; Septoria apiicola; Trichophyton rubrum; T. mentagrophytes; Ustilago spp.; Venturia inaequalis; and Verticillium dahliae.*

- 10 More preferably, the present invention is directed to the prophylactic or therapeutic treatment of infection by a fungal pathogen of plants, even more preferably a fungal pathogen of plants selected from the group consisting of *Alternaria* spp.; *A. mellae*; *A. oligosporus*; *B. granulatus*; *B. cinerea*; *B. fabae*; *C. purpurea*; *C. ribicola*; *E. purpureascens*; *F. annosus*; *F. oxysporum*; *G. graminis* var. *tritici*; *G. cingulata*; *G. juniperi-virginianae*; *M. fructicola*; *P. alfalfae*; *P. infestans*; *P. sulphureus*; *Puccinia* spp.; *S. apiicola*; *Ustilago* spp.; *V. inaequalis*; and *V. dahliae*; and still more preferably, a fungal pathogen of monocotyledonous plants selected from the group consisting of *C. purpurea*; *G. graminis* var. *tritici*; *Puccinia* spp.; and *Ustilago* spp..
- 20 In a particularly preferred embodiment, the present invention provides a method of treatment of infection of a plant by the fungal pathogen *Gaeumannomyces graminis* var. *tritici*, comprising administering an effective amount of a sugar acid thereto for a time and under conditions sufficient to inhibit or prevent fungal growth or reproduction. The plant to which this embodiment of the invention is directed may be any of the
- 25 natural hosts of *G. graminis*, and preferably, a wheat plant or a close relative or progenitor species of wheat, such as, for example, *Triticum aestivum*, *T. tauschii*, or *Hordeum vulgare*, amongst others.

As used herein, the term "sugar acid" shall be taken to refer to the carboxylic acid derivative of any monosaccharide, disaccharide or polysaccharide, whether or not said

30 carboxylic acid derivative is in the anionic form, or a salt, or contains other

- 21 -

substituent groups added thereto, such as, for example, one or more phosphorous atoms or phosphorous-containing moieties. The term "sugar acid" further encompass any mono-carboxylic acid, dicarboxylic acid or tricarboxylic acid derivatives of an aldose.

5

Preferably, but not necessarily exclusively, the sugar acid is not a keto-acid. Additionally, whilst acceptable, it is particularly preferred that the sugar acid used in the performance of the invention is not in the lactone form. Accordingly, notwithstanding that the lactone form may be present in any composition comprising 10 the sugar acid, the invention preferably extends to the use of the sugar acid and not the lactone in the inventive method described herein.

Preferably, the sugar acids contemplated for use in accordance with the present invention are aldonic, aldarcic, or uronic acids. Those skilled in the art are aware that 15 aldonic acids can be produced naturally or synthetically by the oxidation of an aldose at the aldehydic carbon atom, either using weak oxidizing agents, such as, for example, sodium hypiodate, or alternatively, specific enzymes. In contrast, the aldarcic acids are produced using stronger oxidising agents which act at both the aldehydic carbon atom and the carbon atom bearing the primary hydroxyl group, whereas in the 20 uronic acids only the carbon atom bearing the primary hydroxyl group is oxidised. Preferably, the sugar acid used in the performance of the present invention is a derivative of D-glucose, in particular the aldonic acid gluconic acid; and/or the aldarcic acid, glucaric acid; and/or the uronic acid glucuronic acid. The use of sugar acid derivatives of D-galactose, in particular galactonic acid and/or galactaric acid, and/or 25 galacturonic acid, is also contemplated by the present invention. The use of sugar acid derivatives of D-mannose, in particular mannonic acid and/or mannonaric acid, and/or mannonuronic acid, is also contemplated by the present invention. Alternatively, the present invention also contemplates the use of a sugar acid selected from the group consisting of malic acid, and ascorbic acid, in the performance of the present 30 invention.

- 22 -

In a particularly preferred embodiment, the present invention is directed to the use of gluconic acid and/or mannonic acid and/or galacturonic acid, and, more particularly, to the use of gluconic acid.

- 5 By "effective amount" of a sugar acid is meant an amount which is effective in preventing the growth and/or reproduction of the fungal pathogen, or alternatively, killing the fungal pathogen, without significant adverse effects on the health or viability of the plant or animal to which the sugar acid is administered. The effective amount of sugar acid administered will vary depending upon the nature of the fungal pathogen, 10 the sugar acid being administered, and the mode in which the sugar acid is provided (i.e. in the form of a biocontrol agent or purified sugar acid, amongst others). Persons skilled in the art will be capable of determining an effective amount of any sugar acid to be administered, by standard empirical means, the only requirement being the availability of a suitable bioassay for the fungal pathogen. Such methods will be well- 15 known to those skilled in the art, or are described herein. In general, it is not essential to the performance of a bioassay which tests the growth and/or viability of a fungal pathogen to include host cells which the fungus normally infects, provided that appropriate *in vitro* culture conditions have been established which permit the growth of the fungal pathogen. If no such assay is available, then bioassays may be 20 conducted using appropriate animal or plant hosts, or isolated cells or tissues, as a source of nutrient for the fungal pathogen. In the particular case of human subjects, bioassays, other than those used in human trials, may be conducted using appropriate animal models, in particular a mammalian host of a fungal pathogen of humans, such as, for example, mice, rats, or rabbits, or isolated mammalian cells, in particular 25 cultured fibroblast cells.

In this regard, the present inventors have found the agar plug assay described by Poplawsky *et al.* (1988) to be particularly useful for determining the growth and/or viability of a wide range of fungal pathogens of plants, including *Alternaria spp.*; *A. mellae*; *A. oligosporus*; *B. granulatus*; *B. cinerea*; *E. purpurescens*; *F. annosus*; *G.* 30 *graminis var tritici*; *M. fructicola*; *P. sulphureus*; and *V. dahliae*.

- 23 -

To determine the efficacy of any particular sugar acid in controlling a fungal pathogen, various dosages of the sugar acid are tested for their ability to slow or inhibit fungal growth, or alternatively, to kill the fungal pathogen, compared to the effectiveness of one or more negative and/or positive control compounds. Suitable negative controls include the use of a suitable growth medium comprising, as a substitute for the sugar acid being tested, the corresponding aldose sugar, or corresponding lactone, or alternatively, the absence of the test compounds from the growth medium. A suitable positive control includes the use of a suitable growth medium comprising gluconic acid at a concentration which is known to inhibit the growth of the fungal pathogen being tested, or which is known to kill the fungal pathogen being tested.

Once the parameters have been established within which a particular sugar acid will inhibit fungal growth and/or reproduction, it is preferred for the sugar acid to be tested further to ensure that it does not produce adverse effects or severe contraindications on the host when used within those parameters.

The purified sugar or biocontrol agent is generally administered, in the case of therapeutic treatments, to the site of infection. Alternatively, in the case prophylactic treatments, the purified sugar acid or biocontrol agent will generally be administered to a probable infection site, or at least in a form suitable for transport to a probable infection site.

Various modes of administration of the sugar acid to a plant or animal will be known to those skilled in the art, and the present invention is not to be limited by the nature of the formulation used. Because non-modified sugar acids are soluble hydrophilic molecules, sprays, solutions, lotions and topical ointments for administration are readily formulated without the need for chemical solvent-based solubilising agents, which may be detrimental to the plant or animal cells.

Conveniently, the sugar acid is administered to a plant or plant cell in the form of an

- 24 -

aqueous solution, in particular a spray, applied to the infection site and/or the soil or other growth medium. The application of sugar acids in solid or powdered form is not to be excluded. Optionally, a wetting agent, such as, for example, a non-ionic detergent, may be included to facilitate access of the sugar acid to the fungal pathogen. Wetting agents comprising ionic detergents which are alkaline in nature are less desirable, because they may have a pH-neutralising effect, or even an alkalating effect, on the sugar acid. As will be known to those skilled in the art, the hyphae of fungal pathogens may penetrate the epidermal layers of the plant tissues, and, as a consequence, the wetting agent may further assist in the penetration of the sugar acid to underlying cells of the root, stem, or leaf. Additionally, the epidermal cells of many plant tissues are covered with a waxy layer, which may be penetrated using various wetting agents. Accordingly, the wetting agent may assist the sugar acid in reaching those cells of the plant which are to be treated.

In the treatment of infections by fungal pathogens of animals and humans, the present invention is primarily directed to the treatment of those infections of epidermal cells and keratinised tissues, including the skin, genitalia, and nails. Accordingly, the administration of topical lotions, ointments, and powders is to be preferred for such infections. Those skilled in the art will readily be in a position to produce such formulations, which may include various additional pharmaceutical carriers and/or excipients which are of use in the formulation of skin products.

In addition to being provided in the form of a purified sugar acid, the active ingredient (i.e. the sugar acid) may be administered to the plant or animal in the form of a biocontrol agent which produces the sugar acid when cultured in the presence of a carbon source comprising an aldose. Such biocontrol agents may be isolated from natural sources, or consist of any one or more mutants or derivatives of a naturally-occurring organism, or a genetically-engineered organism, the only requirements being that the biocontrol agent is capable of colonising the tissues or cells which are normally infected by the fungal pathogen, and is capable of producing an anti-fungal effective

- 25 -

amount of a sugar acid. Preferably, the biocontrol agent is further limited in respect of the cell types which it is capable of colonising in the host, such as, for example, a non-pathogenic form of the pathogen in question.

- 5 In a preferred embodiment, the biocontrol agent consists of a non-pathogenic bacterium.

Wherein the sugar acid is for treatment of an infection of animals and/or humans, it is particularly preferred that the biocontrol agent consists of a non-pathogenic strain of  
10 bacterium selected from the group consisting of *Streptococcus sp.*, *Staphylococcus sp.*, *Escherichia coli*, *Acidophilus sp.* and *Lactobacillus sp.*. For the treatment of urethral, intra vaginal and anal infections, non-pathogenic strains of *Escherichia coli*, *Acidophilus sp.* and *Lactobacillus sp.* are preferred.

- 15 For the treatment of plants, it is preferred that the biocontrol agent consists of a non-pathogenic strain of bacterium selected from the group consisting of *Agrobacterium tumefaciens*, *Agrobacterium rhizogenes*, *Agrobacterium radiobacter*, *Frankia sp.*, and *Pseudomonas sp.* In the case of *Agrobacterium sp.*, the strain should optimally be one which does not cause adverse crown gall disease, or produce phytohormones, such  
20 as, for example, auxins, gibberellins, or cytokinins, at levels which are capable of inducing atypical developmental patterns in the plant. Strains suitable for use in the performance of the present invention include, for example, derivatives of *A. tumefaciens strain* LBA4404; derivatives of *A. tumefaciens strain* AGL1; and *Pseudomonas strain* AN5 and derivatives thereof.

25

- In a particularly preferred embodiment, the biocontrol agent consists of an isolate of *Pseudomonas*, exemplified by *Pseudomonas strain* AN5 (Nayudu *et. al*, 1994b) or a mutant or derivative thereof. These strains have been shown by the present inventors to have particular utility in the protection of plants against the take-all fungus, *G. graminis* var. *tritici*, by virtue of their ability to colonize the root rhizosphere of a wheat  
30 plant or other host of *G. graminis* var. *tritici*, and to produce a sugar acid when



- 26 -

cultured in the presence of an aldose substrate.

As applied to a biocontrol agent which produces a sugar acid in its native state, such as, for example, a mutant or derivative of *Pseudomonas* strain AN5, reference herein to "mutants" and "derivatives" shall be taken to mean those mutants with increased colonizing ability and/or increased sugar acid biosynthetic capacity and/or increased sugar acid secretion, compared to the naturally-occurring isolate, including any auxotrophic mutants, replication mutants and recombinant strains that have been produced by the insertion of additional genetic material, such as, for example, extrachromosomal plasmids or integrated DNA, or transposable genetic elements. As used herein, the term "secretion" shall be taken to include both active transport and diffusion processes which result in the extracellular localisation of a sugar acid which is produced by a cell.

As applied to bacteria which do not have the capacity to produce and/or secrete sugar acids in their native state, such as, for example *A. tumefaciens*, the terms "mutant" and "derivative" shall be taken to mean that the natural isolate has been subjected to mutagenesis, and/or genetically-engineered, to produce and/or secrete the sugar acid when grown on an appropriate aldose substrate. This may be achieved, for example, by genetically-engineering or mutating an organism to express a pyrroloquinoline-quinone-dependent (PQQ-dependent) sugar oxidase enzyme.

As applied to bacteria which do not have the capacity to colonise the same cells as the fungal pathogen, the terms "mutant" and "derivative" shall be taken to mean that the natural isolate has been subjected to mutagenesis, and/or genetically-engineered, to have the capacity to colonize the same cells or tissues as those which the fungal pathogen infects.

Particularly useful mutants and derivatives further include those organisms having altered cell membrane or cell wall components. According to this embodiment, the present invention provides a rifampicin-resistant derivative of *Pseudomonas* strain

- 27 -

AN5, designated hereinafter as "*Pseudomonas* strain AN5 *rif*" (AGAL Accession No. NM 00/09624), which exhibits higher anti-fungal activity against *G. graminis* var. *tritici* than the naturally-occurring isolate *Pseudomonas* strain AN5.

- 5 *Pseudomonas* strain AN5 *rif* has been deposited with the Australian Government Analytical Laboratories (AGAL), at 1 Suakin street Pymble 2073, New South Wales, Australia, on 28 January, 2000, under the provisions of the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure, and assigned AGAL Accession No. NM 00/09624.

10

In a further preferred embodiment of the invention, *Pseudomonas* strain AN5 or *Pseudomonas* strain AN5 *rif* are further improved for use as a biocontrol agent in performing the present invention, by the introduction of additional copies of the genetic sequences which, when expressed, enable the organism to produce sugar acids. Such  
15 improvements may be produced by means of standard transformation/transfection procedures for bacteria, or transposon mutagenesis, amongst other procedures known to those skilled in the art.

Means for producing mutants will be well-known to those skilled in the art, and include  
20 the use of chemical and physical mutagens, and transposon mutagenesis, amongst others. Particularly preferred chemical mutagens include EMS and methanesulfonic acid ethyl ester. As will be known to those skilled in the art, EMS generally introduces point mutations into the genome of a cell in a random non-targeted manner, such that the number of point mutations introduced into any one genome is proportional to the  
25 concentration of the mutagen used. Accordingly, in order to identify a particular mutation, large populations of cells are generally treated with EMS and the effect of the mutation is then screened in the mutated cells or, more usually, the progeny cells thereof. Methods for the application and use of chemical mutagens such as EMS are well-known to those skilled in the art .

30

Preferred physical mutagens include the irradiation of cells, in particular ultraviolet and

- 28 -

gamma irradiation of cells, to introduce point mutations into one or more genes present in the genome of the cell, or alternatively, to create chromosomal deletions in the genome. Methods for the application and use of such mutagens are well-known to those skilled in the art.

5

Insertional mutagenesis may be achieved by introducing a DNA molecule which encodes genes for the biosynthesis of sugar acids, into one or more genes present in the genome of the cell in an expressible format, such that the ability of the cell to convert aldose to sugar acid is enhanced. Alternatively, a nucleic acid molecule which  
10 is capable of inactivating a negative regulator of a gene required for the biosynthesis of a sugar acid may be introduced into the cell.

Preferred DNA molecules for introducing genes into cells, in particular bacterial or plant cells, include transposon molecules, and T-DNA molecules. The use of transposons  
15 carries the advantage of providing a marker for the cloning of genetic material capable of encoding molecules required to catalyse or otherwise facilitate the conversion of a carbon source to a corresponding sugar acid. Many transposons are known for use in bacterial and plant systems, including *Tn10* (bacterial), *Tn5* (bacterial), *Spm* (plant), *Ac/Ds* (plant), and *DSG* (plant), and their use is well-documented.

20

Methods for the production of appropriate biocontrol agents using are described herein.

The biocontrol agents, including mutant and derivatives, described herein are of utility  
25 in the preparation of compositions for the treatment of fungal infections in plants and animals, and the present invention clearly extends to any and all such uses. For example, the organisms may be used in fermentation or other culture conditions, to produce the sugar acid, which may be then be extracted from the cells using conventional extraction and/or purification procedures, or alternatively, secreted into  
30 the growth medium.

- 29 -

The present invention further provides a phytoprotective composition for the treatment of a fungal infection of a plant comprising an effective amount of a sugar acid in combination with a phytopathologically-acceptable diluent or wetting agent.

- 5 The wetting agent may be any compound which is capable of permeating the epidermal layer and/or the waxy layer of a plant tissue, such as, but not limited to, a non-ionic detergent.

- The concentration of the sugar acid in such compositions will vary depending upon the fungal pathogen, the progression of the disease, the tolerance of the plant to mild acidification, and the soil type. For plants which are less tolerant to acidification, a weaker acid, such as, for example, gluconic acid, may be preferred, in which case, a higher concentration of the sugar acid may be required to alleviate symptoms on the plant. Stronger acids, such as glucuronic acid and glutaric acid, may be used at lower concentrations than gluconic acid, however the suitability of any particular sugar acid for a particular fungal infection should be determined empirically in trials prior to large-scale applications. Such trials are well within the ken of those skilled in the art.

- Preferably, the concentration of sugar acid in the phytoprotective compositions of the invention is in the range of about 0.001% (w/v) to about 1% (w/v) sugar acid, more preferably in the range of about 0.01% (w/v) to about 1% (w/v) sugar acid, and more preferably in the range of about 0.01%(w/v) to about 0.5% (w/v) sugar acid, and even more preferably in the range of about 0.01%(w/v) to about 0.1% (w/v) sugar acid.

- 25 In an alternative embodiment, the phytoprotective composition comprises a biocontrol agent which produces the sugar acid in the presence of an appropriate aldose substrate by virtue of the expression of a PQQ-dependent sugar oxidase enzyme therein. Additionally, the phytoprotective composition may be in the form of a spray, emulsion, or dry powder.

30

The present invention further provides a composition for the treatment of a fungal

- 30 -

infection in a human or other mammal comprising an effective amount of a sugar acid in combination with one or more pharmaceutically-acceptable carriers or diluents. As with other compositions described herein, those compositions for animal use may comprise a biocontrol agent which expresses a PQQ-dependent sugar oxidase enzyme. The composition of the present invention is particularly directed to the treatment of conditions associated with epidermal and sub-cutaneous infections, such as, for example, those conditions caused by the dermatophytes *T. rubrum*, *T. mentagrophytes*, *E. floccosum*, *M. canis*, *C. albicans*, and *P. orbiculare* (*M. furfur*). Accordingly, it is preferred that the composition of the invention be formulated for topical application, including intra vaginal, intra-anal, intra-nasal, and intra-oral uses. Emulsions, lacquers, spray powders, and dry powders are also contemplated by the invention. Except insofar as any conventional media or agent is incompatible with an active ingredient, use thereof in the therapeutic compositions is contemplated. Supplementary active ingredients can also be incorporated into the compositions.

In light of the nature of the active ingredient and the intended application, it is preferred that compositions for topical application are formulated so as to have a pH in the range of about 2.0 to about 7.0, more preferably in the range of about 2.0 to about 5.0, and more preferably in the range of about 2.5 to about 4.0.

Creams, lotions, ointments, and tinctures comprising the sugar acid of the invention, which are intended for topical or intra-vaginal or intra-anal or intra-aural use, can be prepared in a base comprising any standard lotion or ointment for dermatological use, such as, for example, vanishing cream, sorbolene, glycerol and fatty acid esters thereof, liquid polyethylene glycols including polyoxyethylglycol, ethylene glycol, butylated hydroxanisole, liquid paraffin, dimethicone, sorbitan, cetyl palmitate or other fatty acid, polysorbate, and mixtures thereof.

In such topical compositions, alcohols and other organic solvents are not generally required to maintain solubility of the sugar acid, which is hydrophilic. However, as the present invention includes modified sugar acids which have altered hydrophilicity

- 31 -

compared to their non-modified counterparts, and because such compositions may include less-soluble components, the invention also encompasses the use of non-aqueous base compositions.

5 Powders are generally prepared using a base of zinc oxide, talc, or other homogeneous powder base.

Lacquers for nail applications are generally prepared in a lacquer base comprising, for example, methacrylic acid copolymer, glycerol triacetate, butyl acetate, ethyl acetate,  
10 and ethanol.

Spray powders are prepared using a powdered or aqueous base, such as, for example, talc, sorbitan, or a fatty acid; and will also generally comprise a propellant, such as, for example, ethanol, propane, or butane.

15 Under ordinary conditions of storage and use, these preparations will further contain a preservative to prevent the growth of microorganisms. In any event, it must be stable under the conditions of manufacture and storage and should be preserved against the contaminating action of microorganisms, at least until point-of-sale. This may be  
20 achieved, for example, by using various known anti-bacterial and anti-fungal agents, including parabens, chlorobutanol, phenol, sorbic acid, thimerosal, benzoic acid, phenethyl alcohol, and benzyl alcohol, amongst others. The use of antibiotics, such as, for example, tetracycline, rifampicin, ampicillin, penicillin, and streptomycin, or a derivative thereof, is also encompassed by the present invention.

25 The compositions of the invention may further include another anti-fungal compound to provide broad cross-protection against several different pathogens. Such other anti-fungal compounds include, for example, bifonazole, clotrimazole, econazole nitrate, miconazole nitrate, terbafine hydrochloride, and amorolfine hydrochloride, amongst  
30 others.

- 32 -

Preferably, the formulations are prepared by incorporating the active sugar acid compounds, or a biocontrol agent producing same, in the required effective amount, in an appropriate base with various of the other ingredients enumerated above, as required, preferably followed by filter-sterilization.

5

The active sugar acid and/or biocontrol agent, and compositions comprising same, as described herein, can be produced by any means known to those skilled in the art. Additionally, certain sugar acids, including gluconic acid, are readily available to the public from any one of a number of sources. Alternatively, the sugar acid may be  
10 purified partially or completely using any one of a number of procedures known to those skilled in the art, including chromatographic procedures, such as, for example, separations based on charge, size, hydrophobicity, or affinity. Phase separation techniques, thin layer chromatography, and separations using silica gel are particularly contemplated by the invention. Column chromatographic procedures may be carried  
15 out conveniently under conditions of high pressure (e.g. HPLC).

In one embodiment, the sugar acid is produced by introducing an isolated nucleic acid molecule which encodes a PQQ-dependent sugar acid biosynthetic enzyme to an organism and culturing said organism in the presence of an aldose substrate for a time  
20 and under conditions sufficient to produce a sugar acid. Preferably, the sugar acid is subsequently extracted from the organism or the culture medium. More preferably, the sugar acid is partially or substantially purified from the culture medium, the organism or an extract thereof.

25 The nucleotide sequence which encodes one or more enzymes involved in the biosynthesis of a sugar acid or is complementary to said nucleotide sequence is preferably derived from *Pseudomonas sp.*.

Preferably, the nucleotide sequence of the invention encodes a sugar oxidase enzyme.

30

As used herein, the term "sugar oxidase" shall be taken to refer to a PQQ-dependent

T0520T" 90E06860

- 33 -

enzyme, or a PQQ-dependent enzyme complex, or a number of different enzymes which act in the same biochemical pathway wherein at least one of said enzymes is PQQ-dependent, to convert an aldose to a sugar acid. For example, the term "sugar oxidase" includes the action of an oxidase enzyme, with or without a lactonase enzyme, to convert glucose or galactose to any one or more of their corresponding aldonic, aldaric, or uronic acids (i.e. gluconic acid; glucaric acid; glucaronic acid; and galactonic acid). As will be known to those skilled in the art, the glucose oxidase enzyme *solus* is capable of converting glucose to  $\delta$ -gluconolactone, which may subsequently be oxidised non-enzymatically to a sugar acid. Notwithstanding that the velocity of such a non-enzymatic oxidation reaction is slow compared to the enzyme-catalysed reaction, the activity of glucose oxidase combined with such non-enzymatic oxidation of a lactone to a sugar acid clearly falls within the scope of the term "sugar acid", subject to the requirement that a sugar acid is actually produced as the active anti-fungal compound. The term "sugar oxidase" further encompasses the action of a dehydrogenase enzyme with or without a lactonase enzyme, to convert D-glucose to any one or more of the corresponding sugar acids, gluconic acid and/or glucaric acid and/or glucaronic acid.

By "PQQ-dependent" is meant that the sugar oxidase requires PQQ as a cofactor for optimum enzyme activity. As will be known to those skilled in the art, PQQ is a metal-dependent enzyme cofactor produced primarily by bacteria, wherein the metal is generally calcium, or copper. The advantage of using a PQQ-dependent sugar oxidase in the performance of the invention is that the production of PQQ is not linked to glycolysis, and, as a consequence, there is less glycolytic load on a transgenic cell expressing such a sugar oxidase, compared to the expression of an FAD- or NAD-dependent enzyme.

Preferably, the isolated nucleic acid molecule of the invention comprises sequence of nucleotides set forth in SEQ ID NO: 1 or the nucleotide sequence of the sugar oxidase gene present in cosmid pMN M53 (AGAL Accession No. NM 00/09622).



- 34 -

For the purposes of nomenclature, cosmid pMN M53 comprises the nucleotide sequence of a sugar oxidase-encoding gene derived from *Pseudomonas* strain AN5. To produce cosmid pMN M53, a mutant strain of *Pseudomonas* strain AN5 was produced by Tn5: *uidA* insertional mutagenesis of *Pseudomonas* strain AN5, and  
5 screening for bacterial cells which had lost activity against *G. graminis* var. *tritici* and did not produce anti-fungal effective amounts of sugar acid when cultured in the presence of aldose substrate. A sub-genomic fragment of the mutant strain was obtained and sub-cloned into the cosmid pLAF R3, which includes a gene conferring tetracycline-resistance to cells containing the cosmid. The resulting cosmid clone,  
10 designated pMN M53, contains sufficient structural gene information of *Pseudomonas* sp. to confer on any prokaryotic cell harboring this cosmid, or a derivative nucleic acid molecule thereof having the sugar oxidase-encoding region thereof, the ability to synthesise sugar acids from aldose. Cosmid clone pMN M53 has been deposited with the Australian Government Analytical Laboratories (AGAL), at 1 Suakin street Pymble  
15 2073, New South Wales, Australia, on 27 January, 2000, under the provisions of the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure, and assigned AGAL Accession No. NM 00/09622.

The nucleotide sequence set forth in SEQ ID NO: 1 relates to the terminal 757 bp of  
20 a sugar oxidase-encoding gene contained in cosmid clone pMN M53. To obtain the nucleotide sequence set forth in SEQ ID NO: 1, a sequencing primer was used which annealed to the end of the Tn5: *uidA* insertion in cosmid clone pMN M53. The nucleotide sequence set forth in SEQ ID NO: 1 has less than 50% nucleotide sequence identity overall to any known genes, as determined by BLAST search  
25 analysis. However, BLAST search analysis revealed that a fragment of 23 nucleotides in length derived from SEQ ID NO: 1, comprising nucleotides 553 to 575 of this sequence, has absolute identity to the glucose dehydrogenase-encoding genes of *E. coli*, or *Pantoea citrea*. These limited homologies indicate that the nucleotide sequence present in cosmid clone pMN M53 is unlikely to comprise a glucose dehydrogenase-  
30 encoding gene, however is most likely involved in glucose metabolism. Moreover, functional expression data indicate that there is sufficient structural gene sequence in

- 35 -

cosmid clone pMN M53 to confer on any prokaryotic cell harboring this cosmid, or a derivative nucleic acid molecule thereof having the sugar oxidase-encoding region thereof, the ability to convert glucose to gluconic acid. Clearly, the bacterial sugar oxidase gene is not highly conserved with any other known sugar oxidase, such as, 5 for example, the glucose oxidase genes of *Talaromyces flavus* or *Aspergillus niger*.

Accordingly, the present invention clearly extends to homologues, analogues and derivatives of the *Pseudomonas sp.* nucleotide sequence present in the deposited cosmid designated pMN M53, or the nucleotide sequence present in SEQ ID NO: 1. 10 The full-length nucleotide sequence of the *Pseudomonas sp.* nucleotide sequence present in cosmid pMN M53 is particularly contemplated by the present invention.

For the present purpose, "homologues" of a nucleotide sequence shall be taken to refer to an isolated nucleic acid molecule which is substantially the same as the nucleic 15 acid molecule of the present invention or its complementary nucleotide sequence, notwithstanding the occurrence within said sequence, of one or more nucleotide substitutions, insertions, deletions, or rearrangements.

"Analogues" of a nucleotide sequence set forth herein shall be taken to refer to an 20 isolated nucleic acid molecule which is substantially the same as a nucleic acid molecule of the present invention or its complementary nucleotide sequence, notwithstanding the occurrence of any non-nucleotide constituents not normally present in said isolated nucleic acid molecule, for example carbohydrates, radiochemicals including radionucleotides, reporter molecules such as, but not limited 25 to DIG, alkaline phosphatase or horseradish peroxidase, amongst others.

"Derivatives" of a nucleotide sequence set forth herein shall be taken to refer to any isolated nucleic acid molecule which contains significant sequence identity to said sequence or a part thereof. Generally, the nucleotide sequence of the present 30 invention may be subjected to mutagenesis to produce single or multiple nucleotide substitutions, deletions and/or insertions. Nucleotide insertional derivatives of the

- 36 -

nucleotide sequence of the present invention include 5' and 3' terminal fusions as well as intra-sequence insertions of single or multiple nucleotides or nucleotide analogues. Insertional nucleotide sequence variants are those in which one or more nucleotides or nucleotide analogues are introduced into a predetermined site in the nucleotide sequence of said sequence, although random insertion is also possible with suitable screening of the resulting product being performed. Deletional variants are characterised by the removal of one or more nucleotides from the nucleotide sequence. Substitutional nucleotide variants are those in which at least one nucleotide in the sequence has been removed and a different nucleotide or nucleotide analogue inserted in its place.

Particularly preferred homologues, analogues or derivatives include any one or more isolated nucleic acid molecules selected from the following:

- (i) an isolated nucleic acid molecule which comprises a nucleotide sequence which is at least about 50% identical to at least about 30 contiguous nucleotides of SEQ ID NO: 1 or a complementary sequence thereto;
- (ii) an isolated nucleic acid molecule which comprises a nucleotide sequence which is at least about 50% identical to at least about 30 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622);
- (iii) an isolated nucleic acid molecule which is capable of hybridising under at least low stringency conditions to at least about 30 contiguous nucleotides of SEQ ID NO: 1 or a complementary sequence thereto;
- (vi) an isolated nucleic acid molecule which is capable of hybridising under at least low stringency conditions to at least about 30 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622); and
- (vii) an isolated nucleic acid molecule which comprises a nucleotide sequence which is degenerate to SEQ ID NO: 1 or the *Pseudomonas* gene sequence contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622).

- 37 -

Preferably, such homologues will be of a sufficient length and sequence identity to the exemplified sequence and deposited clone to encode a polypeptide having sugar oxidase activity. Preferably, because the nucleic acid molecule of the invention encodes a PQQ-dependent enzyme, and this cofactor is prevalent in bacterial cells, the homologue, analogue or derivative thereof is obtained from a bacterial source, more preferably a *Pseudomonas* sp.

However, the present invention clearly contemplates shorter molecules than those which are full-length, which are at least useful in identifying further sugar oxidase-encoding nucleotide sequences falling within the scope of the invention described herein. Preferably, the homologue, analogue or derivative is at least about 100 nucleotides in length, more preferably at least about 500 nucleotides in length, and even more preferably, comprises at least about 1-10 kb of nucleotides in length.

15 Preferably, the percentage identity to the nucleotide sequence of SEQ ID NO: 1 or the deposited clone, is at least about 60%, more preferably at least about 70%, even more preferably at least about 80%, and more preferably at least about 90%, or 95%, or 99%. In determining whether or not two nucleotide sequences fall within a particular percentage identity limitation recited herein, those skilled in the art will be aware that it is necessary to conduct a side-by-side comparison or multiple alignment of sequences. In such comparisons or alignments, differences may arise in the positioning of non-identical residues, depending upon the algorithm used to perform the alignment. In the present context, reference to a percentage identity between two or more nucleotide sequences shall be taken to refer to the number of identical residues between said sequences as determined using any standard algorithm known to those skilled in the art. For example, nucleotide sequences may be aligned and their identity calculated using the BESTFIT programme or other appropriate programme of the Computer Genetics Group, Inc., University Research Park, Madison, Wisconsin, United States of America (Devereaux *et al*, 1984).

30

The homologues, analogues and derivatives may be obtained by any standard

- 38 -

procedure known to those skilled in the art, such as by nucleic acid hybridization (Ausubel *et al*, 1987), polymerase chain reaction (McPherson *et al*, 1991) screening of expression libraries using antibody probes (Huynh *et al*, 1985) or by functional assays.

5

In nucleic acid hybridizations, genomic DNA, mRNA or cDNA or a part of fragment thereof, in isolated form or contained within a suitable cloning vector such as a plasmid or bacteriophage or cosmid molecule, is contacted with a hybridization-effective amount of a nucleic acid probe derived from SEQ ID NO: 1 or the deposited clone, for

10

a time and under conditions sufficient for hybridization to occur and the hybridized nucleic acid is then detected using a detecting means. Detection is performed preferably by labelling the probe with a reporter molecule capable of producing an identifiable signal, prior to hybridization. Preferred reporter molecules include radioactively-labelled nucleotide triphosphates and biotinylated molecules.

15

Preferably, variants of the genes exemplified herein, including genomic equivalents, are isolated by hybridisation under medium or more preferably, under high stringency conditions, to the probe.

20 For the purposes of defining the level of stringency, a low stringency is defined herein as being a hybridisation and/or a wash carried out in 6xSSC buffer, 0.1% (w/v) SDS at 28°C or alternatively, as exemplified herein. Generally, the stringency is increased by reducing the concentration of SSC buffer, and/or increasing the concentration of SDS and/or increasing the temperature of the hybridisation and/or wash. A medium  
25 stringency comprises a hybridisation and/or a wash carried out in 0.2xSSC-2xSSC buffer, 0.1% (w/v) SDS at 42°C to 65°C, while a high stringency comprises a hybridisation and/or a wash carried out in 0.1xSSC-0.2xSSC buffer, 0.1% (w/v) SDS at a temperature of at least 55°C. Conditions for hybridisations and washes are well understood by one normally skilled in the art. For the purposes of further clarification  
30 only, reference to the parameters affecting hybridisation between nucleic acid molecules is found in Ausubel *et al*. (1992), which is herein incorporated by reference.

- 39 -

In the polymerase chain reaction (PCR), a nucleic acid primer molecule comprising at least about 20 nucleotides in length, and more preferably at least 30 nucleotides in length, derived from SEQ ID NO: 1 or the deposited clone, is hybridized to a nucleic acid template molecule and specific nucleic acid molecule copies of the template are  
5 amplified enzymatically as described in McPherson *et al*, (1991), which is incorporated herein by reference.

In expression screening of cDNA libraries or genomic libraries, protein- or peptide-encoding regions are placed operably under the control of a suitable promoter  
10 sequence in the sense orientation, expressed in a prokaryotic cell or eukaryotic cell in which said promoter is operable to produce a peptide or polypeptide, screened with a monoclonal or polyclonal antibody molecule or a derivative thereof against one or more epitopes of a sugar oxidase polypeptide and the bound antibody is then detected using a detecting means, essentially as described by Huynh *et al* (1985) which is  
15 incorporated herein by reference. Suitable detecting means according to this embodiment include <sup>125</sup>I-labelled antibodies or enzyme-labelled antibodies capable of binding to the first-mentioned antibody, amongst others.

It will be evident from the foregoing discussion that the bacterial sugar oxidase of the  
20 invention is a PQQ-dependent enzyme. However, because not all cells produce PQQ as a cofactor, in order to produce a sugar acid in accordance with the inventive concept, it may be necessary in certain circumstances to also express the enzymes required for PQQ biosynthesis, in addition to those gene(s) encoding the sugar oxidase enzyme. The present inventors have identified the PQQ operon of  
25 *Pseudomonas* strain AN5, comprising the genes the pqqA, pqqB, pqqC, pqqD, pqqE, and pqqF, which are involved in the production of PQQ.

To produce a functional PQQ cofactor in a cell, it is necessary to ensure that a sufficient number of PQQ-biosynthetic genes are expressed therein to convert one or  
30 more of the precursors of PQQ, in the PQQ biosynthetic pathway, to PQQ, and to insert an appropriate metal ion, such as, for example, Cu(II) or Ca<sup>2+</sup>, therein. The

- 40 -

appropriate substrate, and metal ion, must be either endogenous to the cell, or alternatively, provided exogenously to the cell. In this regard, certain cells may be deficient in only one or two or three or four of the PQQ-biosynthetic genes described herein, and, as a consequence, the present invention clearly encompasses the use of only a sub-set of the five genes exemplified herein. Additionally, if a precursor of PQQ which is later in the biosynthetic pathway is provided to the cell, then the genes which encode enzymes acting earlier in the pathway may not be required. For example, the immediate precursor of PQQ may be provided to a cell which expresses only the pqqE gene, and a functional PQQ cofactor may still be produced therefrom. Such modifications will be readily apparent to those skilled in the art.

Accordingly, the present invention further provides an isolated nucleic acid molecule which comprises a nucleotide sequence encoding one or more polypeptides involved in the biosynthesis of PQQ. Preferably, but not necessarily, such sequences are derived from a bacterial cell, such as, for example, *Pseudomonas* sp.. Several bacterial PQQ-biosynthesis genes have been described and are readily available from public sources.

In a particularly preferred embodiment, the present invention provides a novel isolated nucleic acid molecule comprising one or more of the pqqA, pqqB, pqqC, pqqD, pqqE, and pqqF genes of *Pseudomonas* strain AN5.

Preferably, the isolated nucleic acid molecule of the invention comprises sequence of nucleotides set forth in any one of SEQ ID NOs: 2 to 6, or the nucleotide sequence of the sugar oxidase gene present in cosmid pMN-L2 (AGAL Accession No. NM 00/09621).

For the purposes of nomenclature, cosmid pMN-L2 comprises the nucleotide sequence of the pqqA, pqqB, pqqC, pqqD, pqqE, and pqqF genes derived from *Pseudomonas* strain AN5. To produce cosmid pMN-L2, a mutant strain of *Pseudomonas* strain AN5 was produced by Tn5: *uidA* insertional mutagenesis of

- 41 -

*Pseudomonas* strain AN5, and screening for bacterial cells which had lost activity against *G. graminis* var. *tritici*. A sub-genomic fragment of the mutant strain was obtained and sub-cloned into the cosmid pLAF R3, which includes a gene conferring tetracycline-resistance to cells containing the cosmid. The resulting cosmid contains  
5 sufficient structural gene information of *Pseudomonas* sp. to produce PQQ from its natural substrate in a bacterial cell, to confer on any prokaryotic cell harboring this cosmid, or a derivative nucleic acid molecule thereof having these genes therein, the ability to produce PQQ. Cosmid clone pMN-L2 has been deposited with the Australian Government Analytical Laboratories (AGAL), at 1 Suakin street Pymble 2073, New  
10 South Wales, Australia, on 27 January, 2000, under the provisions of the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure, and assigned AGAL Accession No. NM 00/09621.

The nucleotide sequence set forth in SEQ ID NOs: 2 to 6 relate to the pqqA, pqqB,  
15 pqqC, pqqD, pqqE, and pqqF genes contained in cosmid clone pMN-L2. In particular, SEQ ID NO: 2 consists of the full-length pqqA gene and a fragment of the pqqB gene of *Pseudomonas* strain AN5, obtained using a sequencing primer derived from a conserved region in bacterial pqqB genes. The nucleotide sequence set forth in SEQ ID NO: 3 consists of a fragment of the pqqC gene of *Pseudomonas* strain AN5,  
20 obtained using a sequencing primer derived from a conserved region in bacterial pqqC genes. The nucleotide sequence set forth in SEQ ID NO: 4 consists of a fragment of the pqqD gene of *Pseudomonas* strain AN5, obtained using a sequencing primer derived from a conserved region in bacterial pqqE genes. The nucleotide sequence set forth in SEQ ID NO: 5 consists of a fragment of the pqqE gene of *Pseudomonas*  
25 strain AN5, obtained using a sequencing primer which annealed to the end of the Tn5: *uidA* insertion in cosmid clone pMN-L2. The nucleotide sequence set forth in SEQ ID NO: 6 consists of a fragment of the pqqF gene of *Pseudomonas* strain AN5, and the intergenic region between pqqA and pqqF, and was obtained using a sequencing primer derived from a conserved region in bacterial pqqB genes.

30

The nucleotide sequence set forth in any one of SEQ ID NOs: 2, 3, 5, and 6 have less



- 42 -

than 90% nucleotide sequence identity overall to any known PQQ-biosynthesis genes, whilst there is no significant nucleotide sequence identity to SEQ ID NO:4 overall, as determined by BLAST search analysis. However, BLAST search analysis revealed that smaller fragments, of less than 42 contiguous nucleotides in length derived from  
5 any one of SEQ ID NOs: 2 to 6, have greater identities to prior PQQ-biosynthesis genes.

Accordingly, the present invention clearly extends to homologues, analogues and derivatives of the *Pseudomonas sp.* nucleotide sequence present in the deposited  
10 cosmid designated pMN-L2 (AGAL Accession No. NM 00/09621), or the nucleotide sequence present in any one of SEQ ID NOs: 2 to 6. The full-length nucleotide sequence of the *Pseudomonas sp.* pqqA, pqqB, pqqC, pqqD, pqqE, and pqqF genes derived from cosmid pMN-L2 is particularly contemplated by the present invention.

15 Particularly preferred homologues, analogues or derivatives include any one or more isolated nucleic acid molecules selected from the following:

- (i) an isolated nucleic acid molecule which comprises a nucleotide sequence which is at least about 90% identical to at least about 50 contiguous nucleotides of any one of SEQ ID NOs: 2 to 6 or a complementary sequence thereto;
- 20 (ii) an isolated nucleic acid molecule which comprises a nucleotide sequence which is at least about 90% identical to at least about 50 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621);
- (iii) an isolated nucleic acid molecule which is capable of hybridising under at least  
25 low stringency conditions to at least about 50 contiguous nucleotides of any one of SEQ ID NOs: 2 to 6 or a complementary sequence thereto;
- (iv) an isolated nucleic acid molecule which is capable of hybridising under at least low stringency conditions to at least about 50 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL  
30 Accession No. NM 00/09621); and
- (v) an isolated nucleic acid molecule which comprises a nucleotide sequence which

- 43 -

is degenerate to any one of SEQ ID NOs: 2 to 6 or the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621).

- 5 Preferably, such homologues will be of a sufficient length and sequence identity to the exemplified sequence and deposited clone to encode functional PQQ-biosynthesis enzymes. However, the present invention clearly contemplates shorter molecules than those which are full-length, which are at least useful in identifying further PQQ-biosynthesis genes falling within the scope of the invention described herein.
- 10 Preferably, the homologue, analogue or derivative is at least about 100 nucleotides in length, more preferably at least about 500 nucleotides in length, and even more preferably, comprises at least about 1-10 kb of nucleotides in length.

- Preferably, the percentage identity to the nucleotide sequence of SEQ ID NO: 1 or the
- 15 deposited clone, is at least about 90%, more preferably at least about 95%, even more preferably at least about 97%, and more preferably at least about 99%, as determined using standard nucleotide sequence analysis software.

- Preferably, the hybridization stringency is at least moderate stringency, and more
- 20 preferably a high stringency hybridization is employed to identify new sequences.

- As with homologues, or the sugar oxidase-encoding genes of the invention described herein, homologues, analogues and derivatives of a PQQ biosynthesis gene may be obtained by any standard procedure known to those skilled in the art, such as by
- 25 nucleic acid hybridization (Ausubel *et al*, 1987), polymerase chain reaction (McPherson *et al*, 1991) screening of expression libraries using antibody probes (Huynh *et al*, 1985) or by functional assays.

- Although not intending to limit the present invention to any one theory or mode of
- 30 action, it is proposed that *Pseudomonas* strain AN5 or a derivative thereof, in particular *Pseudomonas* strain AN5 *rif* (AGAL Accession No. NM 00/09624), or another organism

- 44 -

carrying the sugar oxidase-encoding nucleotide sequences described herein (optionally with the PQQ-biosynthesis gene nucleotide sequences hereinbefore described), oxidizes an aldose such as D-glucose at the aldehydic carbon atom to form the corresponding sugar acid, wherein the first step in this conversion is catalysed  
5 by the glucose oxidase (GOD) activity of the PQQ-dependent sugar oxidase, involving the formation a lactone, and wherein the second step in this conversion is catalysed by the lactonase activity of the PQQ-dependent sugar oxidase.

Accordingly, in those embodiments of the invention which do not employ an organism  
10 in which the genes of the invention are known to be expressed, it is necessary to introduce those genes to the organism in an expressible format. Because the genes of the invention are bacterially-derived, the sugar oxidase-encoding genes present in cosmid pMN M53, and the PQQ operon of cosmid pMN-L2 contain the requisite regulatory sequences for expression in most bacterial cells, in particular *Pseudomonas*  
15 *sp.*

The present invention further provides for the configuration of the inventive genes described herein in an expressible format in both prokaryotic and eukaryotic cells. In most cases, this requires positioning the structural protein-encoding regions of the  
20 genes described herein in operable connection with one or more regulatory sequences required for expression in a particular cell type, or under a particular set of environmental conditions.

For expression in eukaryotic cells, the structural gene sequences of the invention may  
25 be further modified by the inclusion of intron sequences from known eukaryotic genes to improve the stability of mRNA encoded by said structural genes, or otherwise increase expression. For example, to improve expression in plant cells, the intron sequences of the first intron of the rice actin gene, or the maize *Adh1* gene, or the *Arabidopsis thaliana Adh1* gene are particularly useful.

30

It is also within the scope of the invention to include modifications of the exemplified

- 45 -

nucleotide sequences, or modifications of the genes present in the microorganism deposits, which have been made for the purposes of adapting the codon usage of the bacterial gene to that which is optimum in the organism into which the gene is to be expressed. Such codon usage modifications are well known in the art and may be readily carried out by a skilled person. Accordingly, degenerate sequences to the exemplified sequences are particularly contemplated by the present invention.

Accordingly, the present invention clearly extends to the use of gene constructs designed to facilitate the introduction and/or expression of the nucleic acid molecule of the invention.

To express the nucleic acid molecule in a prokaryotic cell, such as a bacterial cell, or a eukaryotic cell, such as an insect cell, mammalian cell, plant cell or yeast cell, it is preferred that the structural protein-encoding region be placed operably under the control of a strong universal promoter, or a promoter sequence which is capable of regulating expression in response to various external stimuli. Persons skilled in the art will be in a position to select appropriate promoter sequences for expression of the nucleic acid molecule without undue experimentation.

Reference herein to a "promoter" is to be taken in its broadest context and includes the transcriptional regulatory sequences of a classical eukaryotic genomic gene, including the TATA box which is required for accurate transcription initiation, with or without a CCAAT box sequence and additional regulatory elements (i.e. upstream activating sequences, enhancers and silencers) which alter gene expression in response to developmental and/or external stimuli, or in a tissue-specific manner. In the context of the present invention, the term "promoter" also includes the transcriptional regulatory sequences of a classical prokaryotic gene, in which case it may include a -35 box sequence and/or a -10 box transcriptional regulatory sequences.

In the present context, the term "promoter" is also used to describe a synthetic or fusion molecule, or derivative which confers, activates or enhances expression of said

- 46 -

sense molecule in a cell. Preferred promoters may contain additional copies of one or more specific regulatory elements, to further enhance expression and/or to alter the spatial expression and/or temporal expression of a nucleic acid molecule to which it is operably connected. For example, copper-responsive regulatory elements may be placed adjacent to a heterologous promoter sequence driving expression of a nucleic acid molecule to confer copper inducible expression thereon.

Placing a nucleic acid molecule under the regulatory control of a promoter sequence means positioning said molecule such that expression is controlled by the promoter sequence. A promoter is usually, but not necessarily, positioned upstream or 5' of a nucleic acid molecule which it regulates. Furthermore, the regulatory elements comprising a promoter are usually positioned within 2 kb of the start site of transcription of the structural protein-encoding nucleotide sequences, or a chimeric gene comprising same. In the construction of heterologous promoter/structural gene combinations it is generally preferred to position the promoter at a distance from the gene transcription start site that is approximately the same as the distance between that promoter and the gene it controls in its natural setting, i.e., the gene from which the promoter is derived. As is known in the art, some variation in this distance can be accommodated without loss of promoter function. Similarly, the preferred positioning of a regulatory sequence element with respect to a heterologous gene to be placed under its control is defined by the positioning of the element in its natural setting, i.e., the genes from which it is derived. Again, as is known in the art, some variation in this distance can also occur.

Promoters suitable for use in gene constructs of the present invention include those promoters derived from the genes of viruses, yeasts, moulds, bacteria, insects, birds, mammals and plants which are capable of functioning in isolated cells derived from bacteria, yeasts, fungi, animals, or plants, including monocotyledonous and/or dicotyledonous plants, and/or cells, tissues and organs derived from the isolated cells. The promoter may regulate gene expression constitutively, or differentially with respect to the tissue in which expression occurs or, with respect to the developmental stage

- 47 -

at which expression occurs, or in response to external stimuli such as physiological stresses, pathogens, or metal ions, amongst others.

Examples of promoters useful in performing this embodiment include the CaMV 35S  
5 promoter, NOS promoter, octopine synthase (OCS) promoter, *Arabidopsis thaliana*  
SSU gene promoter, napin seed-specific promoter, P<sub>32</sub> promoter, BK5-T *imm* promoter,  
lac promoter, tac promoter, phage lambda  $\lambda_L$  or  $\lambda_R$  promoters, CMV promoter (U.S.  
Patent No. 5,168,062), lacUV5 promoter, SV40 early promoter (U.S. Patent No.  
5,118,627), SV40 late promoter (U.S. Patent No. 5,118,627), adenovirus promoter,  
10 baculovirus P10 promoter, or polyhedrin promoter (U.S. Patent Nos. 5,243,041,  
5,242,687, 5,266,317, 4,745,051 and 5,169,784), bacteriophage T7 promoter,  
bacteriophage T3 promoter, SP6 promoter, SV40 early promoter, RSV-LTR promoter,  
SCSV promoter, SCBV promoter and the like. In addition to the specific promoters  
identified herein, cellular promoters for so-called housekeeping genes, including the  
15 actin promoters, or promoters of histone-encoding genes, are useful.

Numerous vectors having suitable promoter sequences for expression in bacteria have  
been described, such as for example, pKC30 ( $\lambda$ L: Shimatake and Rosenberg, 1981),  
pKK173-3 (tac: Amann and Brosius, 1985), pET-3 (T7: Studier and Moffat, 1986) or  
20 the pQE series of expression vectors (Qiagen, CA), amongst others.

In a particularly preferred embodiment, the promoter is derived from a *Pseudomonas*  
strain AN5 gene present in cosmid clones pMN M53 (AGAL Accession No. NM  
00/09622) or pMN-L2 (AGAL Accession No. NM 00/09621).

25

The gene construct may further comprise a terminator sequence and be introduced  
into a suitable host cell where it is capable of being expressed.

30 The term "terminator" refers to a DNA sequence at the end of a transcriptional unit  
which signals termination of transcription. Terminators are 3'-non-translated DNA

- 48 -

sequences containing a polyadenylation signal, which facilitates the addition of polyadenylate sequences to the 3'-end of a primary transcript. Terminators active in cells derived from viruses, yeasts, moulds, bacteria, insects, birds, mammals and plants are known and described in the literature. They may be isolated from bacteria,  
5 fungi, viruses, animals and/or plants.

Examples of terminators particularly suitable for use in the gene constructs of the present invention include the nopaline synthase (NOS) gene terminator of *Agrobacterium tumefaciens*, the terminator of the Cauliflower mosaic virus (CaMV) 35S  
10 gene, the *zein* gene terminator from *Zea mays*, the Rubisco small subunit (SSU) gene terminator sequences and subclover stunt virus (SCSV) gene sequence terminators, amongst others. Those skilled in the art will be aware of additional promoter sequences and terminator sequences which may be suitable for use in performing the invention. Such sequences may readily be used without any undue experimentation.

15 The gene constructs of the invention may further include an origin of replication sequence which is required for replication in a specific cell type, for example a bacterial cell, when said gene construct is required to be maintained as an episomal genetic element (eg. plasmid or cosmid molecule) in said cell. Preferred origins of replication  
20 include, but are not limited to, the *f1*-ori and *colE1* origins of replication.

The gene construct may further comprise a selectable marker gene or genes that are functional in a cell into which said gene construct is introduced.

25 As used herein, the term "selectable marker gene" includes any gene which confers a phenotype on a cell in which it is expressed to facilitate the identification and/or selection of cells which are transfected or transformed with a gene construct of the invention or a derivative thereof.

30 Suitable selectable marker genes contemplated herein include the ampicillin resistance (*Amp<sup>r</sup>*), tetracycline resistance gene (*Tc<sup>r</sup>*), bacterial kanamycin resistance gene

- 49 -

(Kan<sup>r</sup>), phosphinothricin resistance gene, neomycin phosphotransferase gene (*nptII*), hygromycin resistance gene,  $\beta$ -glucuronidase (GUS) gene, chloramphenicol acetyltransferase (CAT) gene and luciferase gene, amongst others.

- 5 Numerous expression vectors suitable for the present purpose have been described and are readily available.

In a preferred embodiment, the subject method comprises the additional first step of transforming the cell, tissue, organ or organism with a nucleic acid molecule of the  
10 invention, in particular the sugar oxidase-encoding sequences with or without additional PQQ-biosynthesis genes, or one or more gene constructs comprising same. As discussed *supra* this nucleic acid molecule may be contained within a gene construct. The nucleic acid molecule or a gene construct comprising same may be introduced into a cell using any known method for the transfection or transformation  
15 of said cell. In the case of eukaryotic organisms, a whole organism may be regenerated from a single transformed cell, using any method known to those skilled in the art.

By "transfect" is meant that the introduced nucleic acid molecule is introduced into said  
20 cell without integration into the cell's genome.

By "transform" is meant that the introduced nucleic acid molecule or gene construct comprising same or a fragment thereof is stably integrated into the genome of the cell.

25 Means for introducing recombinant DNA into plant tissue or cells include, but are not limited to, transformation using CaCl<sub>2</sub> and variations thereof, in particular the method described by Hanahan (1983), direct DNA uptake into protoplasts (Krens *et al*, 1982; Paszkowski *et al*, 1984), PEG-mediated uptake to protoplasts (Armstrong *et al*, 1990) microparticle bombardment, electroporation (Fromm *et al.*, 1985), microinjection of  
30 DNA (Crossway *et al.*, 1986), microparticle bombardment of tissue explants or cells (Christou *et al*, 1988; Sanford, 1988), vacuum-infiltration of tissue with nucleic acid, or



- 50 -

in the case of plants, T-DNA-mediated transfer from *Agrobacterium* to the plant tissue as described essentially by An *et al.* (1985), Herrera-Estrella *et al.* (1983a, 1983b, 1985).

- 5 For microparticle bombardment of cells, a microparticle is propelled into a cell to produce a transformed cell. Any suitable biolistic cell transformation methodology and apparatus can be used in performing the present invention. Exemplary apparatus and procedures are disclosed by Stomp *et al.* (U.S. Patent No. 5,122,466) and Sanford and Wolf (U.S. Patent No. 4,945,050). When using biolistic transformation procedures, the  
10 gene construct may incorporate a plasmid capable of replicating in the cell to be transformed.

Examples of microparticles suitable for use in such systems include 1 to 5  $\mu\text{m}$  gold spheres. The DNA construct may be deposited on the microparticle by any suitable  
15 technique, such as by precipitation.

Alternatively, wherein the cell is derived from a multicellular organism and where relevant technology is available, a whole organism may be regenerated from the transformed cell, in accordance with procedures well known in the art. Plant tissue  
20 capable of subsequent clonal propagation, whether by organogenesis or embryogenesis, may be transformed with a gene construct of the present invention and a whole plant regenerated therefrom. The particular tissue chosen will vary depending on the clonal propagation systems available for, and best suited to, the particular species being transformed. Exemplary tissue targets include leaf disks,  
25 pollen, embryos, cotyledons, hypocotyls, megagametophytes, callus tissue, existing meristematic tissue (e.g., apical meristem, axillary buds, and root meristems), and induced meristem tissue (e.g., cotyledon meristem and hypocotyl meristem).

The term "organogenesis", as used herein, means a process by which shoots and  
30 roots are developed sequentially from meristematic centres.

- 51 -

The term "embryogenesis", as used herein, means a process by which shoots and roots develop together in a concerted fashion (not sequentially), whether from somatic cells or gametes.

- 5 The regenerated transformed plants may be propagated by a variety of means, such as by clonal propagation or classical breeding techniques. For example, a first generation (or T1) transformed plant may be selfed or crossed to another T1 plant and homozygous second generation (or T2) transformants selected. In the case of woody crops, such as citrus and grapes and other plants, which are not readily selfed to make
- 10 homozygous plants, clonal derivatives of primary transformants will need to be crossed to each other to produce homozygous T2 plants. The T2 plant may then be further propagated through classical breeding techniques.

The regenerated transformed organisms contemplated herein may take a variety of

15 forms. For example, they may be chimeras of transformed cells and non-transformed cells; clonal transformants (e.g., all cells transformed to contain the expression cassette); and grafts of transformed and untransformed tissues (e.g., in plants, a transformed root stock grafted to an untransformed scion ).

- 20 It will be apparent from the preceding discussion that the transformed organisms have a variety of applications by virtue of their ability to express a PQQ-dependent sugar oxidase. In fact, such transformed organisms have applications in any field where treatment of a fungal infection is required, as discussed *supra*. In the case of transformed plants, these may themselves exhibit enhanced resistance or tolerance
- 25 to a fungal pathogen.

Accordingly, the present invention clearly provides a method of enhancing the tolerance of a plant to fungal infection comprising expressing in said plant, or a cell, tissue or organ thereof, an isolated nucleic acid molecule which encodes a PQQ-

30 dependent sugar oxidase according to any embodiment described herein. Preferably, nucleotide sequences comprising one or more PQQ-biosynthesis genes are also

- 52 -

expressed in the plant and, optionally if required, an appropriate substrate for the activity of the expressed PQQ-biosynthetic protein is provided to the transformed plant to ensure that a functional cofactor is formed.

- 5 Preferably, the method further comprises the first step of introducing nucleic acid encoding the sugar oxidase and PQQ-biosynthesis genes to the plant cell.

Preferably, the inventive method further comprises the step of regenerating a whole plant from the transformed cell.

10

By "enhanced tolerance" is meant that the plant is less susceptible to a sustained infection by the fungal pathogen, and/or is less likely to develop disease following an initial infection by the fungus, because the fungal pathogen is unable to grow uninhibited on the transformed plant.

15

This aspect of the invention clearly extends to those progeny of the transformed plants which also express the introduced nucleic acid molecules.

The present invention is further described with reference to the accompanying

20 Examples and drawings.

- 53 -

**EXAMPLE 1****Use of *Pseudomonas* strain AN5 as a biocontrol agent against*****G. graminis* var *tritici* (take-all)**

In small scale field trials, the inventors were able to consistently increase wheat yield at different dry-land trial sites in New South Wales, Australia, from between 12% to 36% ( $P < 0.05$ ), by application of *Pseudomonas* strain AN5 (Table 1).

**Table 1**  
**Summary of wheat yields (Kg/plot)**

Trial $\Delta$	AN5	Ba <sub>1</sub>	Ba <sub>2</sub>	Ba <sub>3</sub>	Pf5	Control
Goolgowi	10.23	11.00*	n.t	n.t	8.86 <sup>^</sup>	9.07
Forbes	n 10.76	10.28	11.28*	10.95*	9.70 <sup>^</sup>	9.12
West Wyalong	5.70*	5.88*	5.17	5.41	4.65 <sup>^</sup>	4.32

n.t , not tested; <sup>^</sup>, not significant; \*, significant at  $p < 0.01$ .

15

Subsequently, the Harden District Rural Services (HRS) group has established large scale trials using *Pseudomonas* strain AN5 in acre plots at a trial site at Harden, New South Wales, Australia. Prior to the commencement of the trial, there was significant take-all disease at this site. Following biocontrol treatment using *Pseudomonas* strain AN5, the treated plot monitored through the wheat growing season exhibited 30% to 40% suppression of disease, as determined by the level of white head formation and visual scoring of symptoms on the roots. Additionally, determination of wheat crop yield using a bio-informatic satellite-based global positioning system (GPS) to accurately determine the location of the harvested crop, and an NIH image analyser, indicated that there was 20% increase in wheat yield due to biocontrol protection conferred by *Pseudomonas* strain AN5.

In biocontrol protocols, the survival of *Pseudomonas* strain AN5 bacteria on the roots of plants, and in the soil, is one of the most crucial factors in effective biological control protection. A typical survival pattern of *Pseudomonas* strain AN5 bacteria on the roots of wheat over a season is that they decrease in numbers. The rate of decrease of

5

## 10

Chocolate spot (causative agent *Botrytis fabae*) is a significant disease of faba beans. Currently, fungicides are applied a number of times during the growing season.

15

20

30

- 55 -

enhance tolerance of faba beans to *B. fabae*.

### EXAMPLE 3

#### Identification of an anti-fungal compound in *Pseudomonas* sp. which is active 5 against *G. graminis* var *tritici* (take-all)

##### *Microbiological and Molecular biological methods*

Standard methods were employed as described by Nayudu and Holloway, (1981),  
Nayudu and Rolfe (1987), Nayudu *et. al.*, (1994a) and Nayudu *et. al.*, (1994b).

##### *Bacterial strains*

*Pseudomonas* strains designated AN5, Pf5, and AN5 *rif*, possess anti-fungal activity  
against take-all, and were used in all experiments, unless otherwise stated. The  
mutant strains AN5-MN1 and AN5-MN2 do not possess significant anti-fungal activity  
15 and were used as negative controls unless otherwise stated.

##### *Bioassay procedure*

A modification of the agar plug assay (Poplawsky *et al.*, 1988) was used to assay for  
bioactivity of extracts of *Pseudomonas* strain AN5, or derivative strains thereof, against  
20 take-all fungus, wherein an agar overlay assay was used to test activity of specific  
fractions. This assay involves macerating the take-all fungus grown in Potato Dextrose  
(PD) broth and seeding it to a Potato Dextrose Agar (PDA) overlay. This PDA overlay  
was poured onto thick PDA plates. Fractions to be tested for activity were spotted on  
top of the overlay, and the plates were dried and incubated at 16°C for 3-5 days.

##### *Extraction and analysis of the anti-fungal compound*

*Pseudomonas* sp. strain AN5 bacteria were cultured in 250ml flasks, at 25°C, for two  
days, using potato dextrose broth as the growth medium. Following this culture period,  
150 ml isopropanol was added to 90ml of cell culture, and the solution mixed by  
30 shaking for 15 minutes, after which time cells were collected by centrifugation for 10  
minutes at 5,000 rpm. The supernatant was removed and evaporated using a

- 56 -

rotavapor at 40°C. The crude evaporate was dissolved in 100ml of ethanol (30ml three times). To the ethanol insoluble triturate, 50ml water was added, followed by 50ml acetone, to precipitate proteinaceous material.

5 The resulting suspension was centrifuged and a total of 0.02ml, drawn from the supernatant as well as from ethanolic solution, was applied by a micropipette (Gilson Pipette) to a silica gel G F254 TLC plate (Aszalos *et al.*, 1968). Thin layer chromatography was performed on the crude extract, using several different solvent systems:

- 10 1. methanol;
2. methanol: chloroform [1:9 (v/v)];
3. chloroform;
4. pyridine: water [1:1 (v/v)];
5. pyridine: water: ethanol [1:1:1 (v/v/v)];
- 15 6. pyridine: water: ethanol [1:1:3 (v/v/v)];
7. 2-propanol: water [17:3 (v/v)];
8. 2-propanol: water [4:1 (v/v)];
9. 2-propanol: water [7:3 (v/v)];
10. acetone: water [9:1(v/v)];
- 20 11. acetone:*n*-butanol:acetic acid:water [8:0:5:0.5:1(v/v/v/v)];
12. *n*-propanol: water [7:1 (v/v)];
13. *n*-propanol: water [7:1.5 (v/v)];
14. *n*-propanol: ethyl acetate: water [5:1:4 (v/v/v)];
15. *n*-propanol: ethyl acetate: water [5:2:3 (v/v/v)];
- 25 16. *n*-propanol: ethyl acetate: water [5.5:2:2.5 (v/v/v)];
17. methyl acetate: 2-propanol: water [18:1:1(v/v/v)];
18. 2-propanol: ethyl acetate: water [1:1:2 (v/v/v)]; and
19. 2-propanol: ethyl acetate: water [6:1:3 (v/v/v)].

30 This large number of solvent systems was used in attempts to improve the resolution of the active anti-fungal compound of *Pseudomonas sp.* strain AN5 on silica TLC

- 57 -

plates.

To determine whether any particular compound in TLC plates possessed anti-fungal activity, the bioassay described *supra* was modified such that the PDA overlay ,  
5 seeded with take-all fungus, was poured onto the TLC plates and incubated for a week at 16°C. Active fractions were identified by the appearance of a clearance zone in the plates, within an opaque background of cultured fungus.

Using this bioassay, the compound having anti-fungal activity in *Pseudomonas* strain  
10 AN5 against take-all fungus did not migrate from the origin using the solvent systems comprising methanol; methanol: chloroform [1:9 (v/v)]; or chloroform. The biological activity was tested on TLC plates as well as after scratching bands and extracting the compounds from plates on PDA plates. In particular, there was a clearance zone at the origins of these TLC plates, as well as on PDA plates having the same active  
15 fraction (Figure 1).

Using TLC in conjunction with this bioassay, the bioactive anti-fungal compound of *Pseudomonas* strain AN5 was shown to have an R<sub>f</sub> value of about 0.7, when a solvent system comprising pyridine: water: ethanol [1:1:1 (v/v/v)], or pyridine: water: ethanol  
20 [1:1:3 (v/v/v)] was used, however resolution of the compound was poor in this system also.

Silica Gel Reverse Phase Thin Layer Chromatography (SGRPTLC) using a solvent system comprising acetonitrile:methanol:water was unable to produce better resolution  
25 than these TLC solvent systems.

We subsequently tested solvent systems usually applied to the separation of carbohydrates, in particular organic solvents of binary or ternary composition. Water is an indispensable component of such solvent systems, because water-free solvents,  
30 or solvents having low water content, produce diffuse spots, as were obtained for crude extracts of AN5 and mutants thereof (Ghebregzabher *et al.*, 1976).



- 58 -

From the large number of solvent systems listed *supra*, only one system, *n*-propanol: ethyl acetate: water has been successful in resolving the anti-fungal component of *Pseudomonas* strain AN5 in TLC procedures, wherein optimum results were obtained using *n*-propanol: ethyl acetate: water [5:2:3 v/v/v]. Data are shown in Figure 2. This solvent system is normally used for separating hexoseamines (Ghebregzabher *et al.*, 1976; Gal, 1968). Accordingly, these data suggested that the anti-fungal compound of *Pseudomonas* strain AN5 might be a carbohydrate-like molecule.

#### EXAMPLE 4

##### 10 Purification of an anti-fungal compound in *Pseudomonas sp.* which is active against *G. graminis var tritici* (take-all)

Adsorption chromatography on columns or on TLC plates is a useful method for separation and purification of simple sugars, sugar derivatives and oligosaccharides. However, this technique is time consuming and frequently results in poor resolution due to band tailing. Therefore, the inventors followed the substantially faster technique of "flash chromatography" to purify the compound (Still *et al.*, 1978). Flash chromatography is basically an air pressure driven hybrid of medium pressure and short column chromatography.

20 Biologically-active extracts of *Pseudomonas* strain AN5, or the mutants AN5-MN1 or AN5-MN2, were separated on silica columns, using SGRPTLC with the *n*-propanol: ethyl acetate: water [5:2:3 v/v/v] solvent system, essentially as described by Still *et al.* (1978).

25 Partially-purified extracts (i.e. column fractions) of *Pseudomonas* strain AN5, or the mutants AN5-MN1 or AN5-MN2, were separated on TLC plates using the standardised solvent system (i.e. *n*-propanol: ethyl acetate: water [5:2:3 v/v/v]) and different bands were scratched and extracted. The extracted compounds of *Pseudomonas* strain AN5 were tested for their anti-fungal activity on PDA plates, using the bioassay described in the preceding Example. The bioassay was also performed using the modified procedure on TLC plates to confirm the activity of the band of interest. The active

- 59 -

fractions, which have similar active band on TLC plates, were pooled for further analysis.

As shown in Figure 3A, bioactive column fractions of *Pseudomonas* strain AN5 were also shown to possess bioactivity using TLC, wherein they migrated to a point corresponding to an R<sub>f</sub> value of about 0.75 on TLC. In contrast, the identical silica gel fractions, extracted from the biologically-inactive mutants AN5-MN1 or AN5-MN2, were inactive in the bioassay conducted on TLC plates with a PDA overlay, suggesting that the active fraction of *Pseudomonas* strain AN5 extracts was acting specifically.

However, the silica gel column fractions obtained from extracts of *Pseudomonas* strain AN5 were not considered to comprise pure compounds, because many bands were observed on TLC plates containing these fractions (Figure 3A).

The bioactive compound was further purified by separating pooled active fractions of *Pseudomonas* strain AN5 on TLC and excising the bands of interest. The compounds in these excised bands were tested for activity against take-all on PDA plates, and shown to possess bioactivity (Figure 4).

## EXAMPLE 5

### **Chemical characterisation of an anti-fungal compound in *Pseudomonas* sp. which is active against *G. graminis* var *tritici* (take-all) as a sugar acid**

The active anti-fungal fractions from *Pseudomonas* strain AN5 were further analysed by <sup>1</sup>H NMR, <sup>13</sup>C NMR, and the mass spectra of compounds determined, to determine the structure of the biologically-active compound.

As shown in Figure 5A, <sup>1</sup>H NMR of the active fraction purified using silica gel and TLC as described in the preceding Example, produced peaks having resonances at 5.09, 3.57, 3.69, 3.39, 3.26, 3.69 and 3.63, which resonances correspond to protons attached to carbon atoms C1, C2, C3, C4, C5, and C6, suggesting that the active compound was a carbon-containing compound. Peaks characteristic of C2 to C6 of

- 60 -

gluconic acid were also observed at 3.99, 3.89, 3.62, 3.62, 3.68 and 3.52.

As shown in Figure 5B,  $^{13}\text{C}$  NMR of the active fraction purified using silica gel and TLC as described in the preceding Example, produced peaks having resonances at 94.67, 75.35, 74.07, 74.02, 72.23 and 63.16, characteristic of carbons C1 to C6 of  $\alpha$ -D-glucose; and peaks having resonances at 98.49, 78.53, 78.34, 76.71, 72.19, and 63.32, characteristic of C1 to C6 of  $\beta$ -D-glucose; and peaks having resonances at 181.2, 76.67, 73.54, 75.16, 73.76 and 65.2, which are characteristic of C1 to C6 of gluconic acid.

As shown in Figure 5C, mass spectral analysis of the active fractions derived from silica gel and TLC as described in the preceding Example, also suggested that D-glucose and gluconic acid were present in the active fraction.

- Proceeding on the basis that the active compound was a sugar acid, pure gluconic acid and other sugar acids were tested for bioactivity against take-all using the PDA plate bioassay. As shown in Figure 6A, purified gluconic acid possessed strong biological activity against take-all. Data presented in Figure 6B also indicated that purified malic acid, ascorbic acid, glutaric acid, and glucuronic acid possessed activity against take-all fungus at the concentrations tested.

Furthermore, the active compound produced by *Pseudomonas* strain AN5 is different to the anti-fungal compounds produced by other bacterial strains. The two bacterial strains, designated *Pseudomonas* strain AN5, and *Pseudomonas* strain Pf5, which have anti-fungal activity against take-all, were tested for the presence of 2, 4-diacetylphloroglucinol according to the procedure of Keel *et al.* (1996). Extracts of these two bacterial strains were also analysed for the presence of amines, sugars, and carbonyl compounds, using art-recognised ninhydrin, silver nitrate, and dinitrophenylhydrazine tests, respectively. Some of the results indicating these differences are summarized below:

### 1. Solubility and pigment production

Phenazine-1-carboxylic acid (PCA) is a pigmented greenish-yellow antibiotic which accumulates in cultures of *P. fluorescens* strain 2-79 (Gurusiddaiah *et al*, 1986). PCA is highly soluble in chloroform and methylene chloride and insoluble in water, methanol and ethyl acetate. In contrast, the anti-fungal compound produced by *Pseudomonas* strain AN5 is highly-soluble in water. Moreover, *Pseudomonas* strain AN5 does produce coloured pigments while growing in media. Similarly, 2,4-diacetylphloroglucinol-producing strains of *Pseudomonas* sp. produce red pigments when grown on King's B medium (Keel *et al*, 1996). In contrast, no coloured substances were produced by *Pseudomonas* strain AN5 when grown on King's medium (Figure 7).

### 2. Separation on TLC

The TLC profile of the active anti-fungal agent of *Pseudomonas* strain AN5 did not correspond to that observed for known anti-fungal agents. In particular, the sugar acids identified to have anti-fungal activity could not be separated on TLC using the solvents required to resolve previously-identified compounds. For example, on TLC plates of silica gel, using chloroform: methanol [19:1(v/v)], 2,4-diacetylphloroglucinol has an R<sub>f</sub> value of 0.2; and pyoluteorin has an R<sub>f</sub> value of 0.5 (Keel *et al*, 1992). Additionally, using reverse-phase C18 TLC with an acetonitrile: methanol: water [1:1:1(v/v/v)] solvent system, 2,4-diacetylphloroglucinol has an R<sub>f</sub> value of 0.88; pyoluteorin has an R<sub>f</sub> value of 0.75; and pyronitrine has an R<sub>f</sub> value of 0.28 (Rosales *et al*, 1995 and Pfender *et al*, 1993). In contrast, the sugar acid compound of the present invention did not migrate from the origin using a chloroform: methanol [19:1(v/v)] solvent system (Figure 1), and was only resolved poorly using acetonitrile: methanol: water [1:1:1(v/v/v)].

### 3. Proton NMR spectra

In <sup>1</sup>H NMR of PCA, proton peaks are only observed above 7 ppm (Gurusiddaiah *et al*, 1986; Figure 8), whereas no peaks were observed in this region in spectra of the new compound. In proton NMR of 2,4-diacetylphloroglucinol, two peaks at about 6.00 and

- 62 -

2.5 ppm are characteristic of the attachment of hydrogen to the six carbon protons and the six acetyl protons, respectively (Keel *et al*, 1992) and this did not match with proton NMR spectra obtained for crude extracts of *Pseudomonas* strain AN5, or *Pseudomonas* strain Pf5 (Figure 9).

5

In summary, all of the chemical data obtained indicate that the anti-fungal compound of *Pseudomonas* strain AN5 is a carbohydrate, and, in particular, a sugar acid.

#### EXAMPLE 6

10

##### **Sugar acids produce by *Pseudomonas* sp. induce a pH change in culture media**

The take-all fungus was grown on potato dextrose plates with the indicator dye, bromocresol purple (0.015g/l). After 6-7 days of culture, a purple ring developed around take-all, indicating that the media was alkaline (Figure 10B). Thus, the take-all  
15 fungal hyphae grow and releases compounds into the media which are alkaline in nature.

To determine whether this alkalating effect of take-all is modified by the sugar acid of the invention, the parental strain, *Pseudomonas* strain AN5, and the mutant strains,  
20 AN5-MN1, AN5-MN2, and AN5-MN3, were streaked onto PDA supplemented with bromocresol purple (0.015g/l). Data presented in Figure 10A indicate that *Pseudomonas* strain AN5 acidifies media supplemented with 2% (w/v) glucose when incubated therein, as detected by a yellow halo on PDA plates in the presence of with bromocresol purple. In contrast, the mutant strain AN5-MN1 was unable to produce  
25 this yellow halo after 3-4 days (Figure 10A). The plates with the mutants on them went purple, which is an indicator of alkalinity. The absence of this colour change was noted for all mutants. These data indicate that, whereas *Pseudomonas* strain AN5 decreases the pH of the PDA growth medium, the mutants increase the pH of PDA. The correlation of these data with the anti-fungal activity of these bacterial strains  
30 further supports the conclusion that the anti-fungal compound produced by *Pseudomonas* strain AN5 is acidic in nature.

- 63 -

The effects of different concentrations of purified acids on the take-all root disease is shown in Table 2. Data presented in Table 2 suggest that acidification of the medium may play an important role in protecting against take-all. In particular, whilst gluconic acid confers protection against take-all, the sodium salt of gluconic acid did not confer  
5 significant protection against the fungal pathogen.

### EXAMPLE 7

#### ***Pseudomonas* strain AN5 produces different sugar acids**

*Pseudomonas* strain AN5 grown on nutrient agar, Kings B medium, or Malt agar,  
10 without aldose substrate, does not produce significant amounts of sugar acids, as indicated by the pH of the media. Extracts from these media have little or no biological activity against take-all fungus. Additionally, *Pseudomonas* strain AN5 on potato agar (which contains starch as its main carbon source) does not produce sugar acid, and the media is alkaline, and there is no anti-fungal biological control activity of extracts  
15 of *Pseudomonas* strain AN5 from potato agar.

In contrast, strong biological activity is detected when *Pseudomonas* strain AN5 is extracted from potato dextrose medium which contains glucose as a carbon source. Furthermore, the pH of this medium turns acidic in nature by virtue of the production  
20 of gluconic acid.

We have demonstrated that, if a different carbon source is added to potato agar inoculated with *Pseudomonas* strain AN5, such as galactose or mannose, then sugar acids are produced. The media extracted from such cultures have biological activity  
25 against take-all fungus.

Data presented in Figures 11A and 11B indicate that galacturonic acid is produced from cultures of *Pseudomonas* strain AN5 grown on PD medium supplemented with galactose.

30

Additionally, data presented in Figures 12A and 12B indicate that mannonic acid is

- 64 -

produced from cultures of *Pseudomonas* strain AN5 grown on PD medium supplemented with mannose.

However, the biological activities against take-all of mannonic acid or galacturonic acid are not as strong as gluconic acid. From what is known about the efficiency of conversion of different aldose substrates by *Aspergillus* sp., it is possible that glucose is merely converted more efficiently into sugar acids than mannose or galactose.

#### EXAMPLE 8

##### **Broad anti-fungal activity of gluconic acid produced by *Pseudomonas* strain AN5**

*Pseudomonas* strain AN5 was tested against a range of microorganisms for biological control as listed in Table 3, using the PDA plate bioassay, to determine the efficacy of gluconic acid in controlling growth of these pathogens. The anti-fungal agent produced by *Pseudomonas* strain AN5 showed activity against a broad spectrum of fungi which represent plant pathogens, human pathogens and saprophytes. When tested against bacterial species there were some Gram negative and Gram positive species which were inhibited by the agent produced by *Pseudomonas* strain AN5, however the species-spectrum of protection was not as broad as in the case of fungi. The range of inhibition observed was in the range of total protection to only partial protection.

- 65 -

TABLE 2

Sugar acid	Amount (mg)	media pH	Clearance zone radii (cm)	pKa
Malic acid	7.5		1.0	3.4
	12.5		2.0	
	25.0	1.5	2.5	
Ascorbic acid	7.5		0.0	4.17
	12.5		0.9	
	25.0	1.9	2.0	
Glutaric acid	7.5		1.5	4.31
	12.5		2.0	
	25.0	2.0	2.5	
Glucuronic acid	7.5		0.0	
	12.5		1.0	
	25.0	1.7	2.0	
Gluconic acid	7.5		0.7	3.6
	12.5		1.0	
	25.0	about 5.0	2.0	
Sodium gluconate	7.5		0.0	
	12.5		0.0	
	25.0	about 7.0	0.0	
Galacturonic acid	7.5		0.7	4.76
	12.5		2.0	
	25.0	1.7	2.5	
Acetic acid	1.05		1.5	
	2.1		3.0	
	4.2 to 8.4	2.4	>3.0	



- 66 -

**EXAMPLE 9****Mutant strains of *Pseudomonas* sp. which have modified activity  
against *G. graminis* var. *tritici* (take-all)**

The inventors have isolated naturally-occurring mutants of *Pseudomonas* AN5  
5 bacteria, and genetically engineered new strains of *Pseudomonas* AN5 bacteria, which  
produce different amounts of sugar acids when grown on aldose substrates. This has  
been achieved, for example, by culturing the parent strain on different antibiotics, by  
introducing a multi-copy plasmid with additional anti-fungal genes into *Pseudomonas*  
strain AN5, or by transposon mutagenesis of *Pseudomonas* strain AN5. Strains which  
10 produce less EPS, to facilitate the secretion of more sugar acid into the surrounding  
medium have also been produced. These mutants and derivatives of *Pseudomonas*  
strain AN5 produce larger clearance zones in agar plate bioassays. These strains  
have been tested for biological control protection against take-all in controlled  
environment cabinet trials.

15

***Mutants having reduced anti-fungal activity***

Mutants having reduced anti-fungal activity are particularly useful as negative controls  
in experiments to identify anti-fungal compounds, or as vectors into which different  
anti-fungal properties, such as genes encoding sugar oxidases, may be introduced.

20

One particularly useful mutant, designated *Pseudomonas* strain AN5-M1, is a single  
transposon mutant strain of AN5 which has lost anti-fungal activity. A Tn5 transposon  
has been inserted into a gene which is required for activity against take-all in this  
mutant.

25

Three transposon mutants, AN5-MN1, AN5-MN2, and AN5-MN3 were isolated which  
have lost biocontrol activity, do not produce the anti-fungal metabolite and are unable  
to control the take-all root disease of wheat. These mutants cannot utilise glucose in  
a similar pathway to the parent strain, *Pseudomonas* strain AN5. These mutants are  
30 deficient in an enzyme which converts glucose to sugar acid.

- 67 -

TABLE 3

Host range of protection conferred by *Pseudomonas* strain AN5 cultured in the presence of glucose substrate

TYPE OF ORGANISM	SPECIES TESTED	MODE OF INFECTION
Deuteromycetes	<i>E. pupurescens</i>	Saprophytic
	<i>Alternaria sp.</i>	Saprophytic
	<i>A. oligosporus</i>	Saprophytic
	<i>M. fructocola</i>	Pathogenic
	<i>B. cinerea</i>	Pathogenic
	<i>V. dahliae</i>	Pathogenic /Saprophytic
Basidiomycetes	<i>F. annosus</i>	Pathogenic
	<i>A. mellea</i>	Pathogenic
	<i>B. granulatus</i>	Mycorrhizal
	<i>P. suphureus</i>	Saprophytic
Yeast	<i>S. cerevisiae</i>	Saprophytic
Gram negative bacterium	number of species	Varied
Gram positive bacterium	number of species	Varied

#### *Mutants having reduced anti-fungal activity*

Mutants having reduced anti-fungal activity are particularly useful as negative controls in experiments to identify anti-fungal compounds, or as vectors into which different anti-fungal properties, such as genes encoding sugar oxidases, may be introduced.

One particularly useful mutant, designated *Pseudomonas* strain AN5-M1, is a single transposon mutant strain of AN5 which has lost anti-fungal activity. A Tn5 transposon has been inserted into a gene which is required for activity against take-all in this mutant.

Three transposon mutants, AN5-MN1, AN5-MN2, and AN5-MN3 were isolated which

- 68 -

have lost biocontrol activity, do not produce the anti-fungal metabolite and are unable to control the take-all root disease of wheat. These mutants cannot utilise glucose in a similar pathway to the parent strain, *Pseudomonas* strain AN5. These mutants are deficient in an enzyme which converts glucose to sugar acid.

5

Two additional transposon mutants, carrying the Tn5:*uidA* transposon, were identified by virtue of their inability to confer biocontrol against take-all fungus. These mutants were designated PQQ and SOX. As shown in Example 13, the PQQ and SOX mutants contained the Tn5 element in the *pqqD* gene, and sugar oxidase gene, respectively, of the *Pseudomonas* sp. genome.

#### *Mutants having increased anti-fungal activity*

A spectinomycin-resistant strain, designated *Pseudomonas* strain AN5 spec, was isolated as a naturally-occurring mutant of *Pseudomonas* strain AN5, by screening for growth on the antibiotic spectinomycin. *Pseudomonas* strain AN5spec has adequate biocontrol characteristics against take-all fungus.

*Pseudomonas* strain AN5 rif (AGAL Accession No. NM 00/09624) was isolated as a naturally-occurring mutant of *Pseudomonas* strain AN5, by screening for growth on the antibiotic rifampicin. Accordingly, *Pseudomonas* strain AN5rif is rifampicin-resistant. Bioassays using this strain indicate that it has superior biocontrol characteristics against take-all fungus, on both PDA plates and in pot trials, compared to the parent strain of *Pseudomonas* strain AN5spec.

*Pseudomonas* strain AN5-M1 was modified by introducing a cosmid comprising the pLAF3 vector with a wild-type region of *Pseudomonas* strain AN5 genome inserted therein. Cosmid pLAF3 is generally multi-copy in *Pseudomonas* sp., however copy number is relatively low (10-15 copies per chromosome), compared to many bacterial plasmids. Transformants were screened for anti-fungal activity against take-all.

30

One transformant was identified which protected against take-all as efficiently as the

- 69 -

parent strain, *Pseudomonas* strain AN5. However, this modified bacterial strain only poorly colonises the roots of wheat and there are very few numbers of bacteria present on the roots compared to the colonising ability of the parent strain, suggesting that, for the transformant, each individual cell which colonises the roots may provide superior protection compared to an individual cell of the parent strain, presumably by producing greater levels of anti-fungal agent on a cell basis. These data also suggest that, by increasing the capacity of a single cell to produce the anti-fungal compound, a more effective biological control strain may be created.

- 10 The inventors have also created a range of genetically-engineered strains which colonize the roots of wheat in a normal manner and show a greater clearance zone in agar plate bioassays.

The inventors have also genetically-engineered a number of novel biocontrol strains that produce higher amounts of anti-fungal agent, either by introducing multi-copy plasmids (eg. *Pseudomonas* strain AN5-M1, and *Pseudomonas* strain AN5-P1) or by obtaining a transposon mutant of this strain (eg. *Pseudomonas* strain AN5-T5).

These enhanced biological control strains were shown to be more potent against take-all in agar plate bioassays by their larger clearance zones. Results with strains *Pseudomonas* strain AN5-P1 and *Pseudomonas* strain AN5-T5 indicated that an increase in biological control protection can be obtained against take-all fungus by increasing the anti-fungal nature of the strain without compromising colonisation ability. Therefore, an increased in anti-fungal activity increases biological control protection ability.

In glasshouse trials, these modified strains were shown to protect significantly better than the parent strain, *Pseudomonas* strain AN5, as determined by the scoring of symptoms on the roots of wheat. In particular, inhibition of growth of *G. graminis* in the presence of these strains was determined following inoculation of pots with the fungus on millet seed. Control samples contained either no added fungus or biocontrol

- 70 -

bacterium, or fungus without biocontrol bacteria. Disease score for take-all was determined, using a scale wherein a numeric indicator is assigned to the severity of the disease, as follows: zero = no disease; 1 = disease which is barely detectable; and 5 = maximum disease on the crown of the plant. At the end of the experiment, the 5 plants were also dried and weighed, and their dry weights expressed as a percentage of the dry weight of control plants. Data presented in Table 4 indicate the mean data obtained over six treatments. Enhanced antibiosis is indicated by the enhanced anti-fungal activities of the genetically-engineered strains, compared to the parental strain.

- 10 In such pot trials, where an excess of take-all fungus was artificially added to the potting medium, these improved biocontrol strains provided significant protection against take-all for much longer periods of time than the parent strain. *Pseudomonas* strain AN5-P1, and *Pseudomonas* strain AN5-T5, which produce higher concentrations of sugar acids, have the potential to provide greater protection when they are lower in 15 number on wheat roots. Therefore, these strains should give better protection against take-all when reduced in number on the roots of wheat during drier winter growing seasons.

#### EXAMPLE 10

##### 20 Mass spectrum analysis of sugar acids produced by *Pseudomonas* strain AN5 rif

*Pseudomonas* strain AN5 rif (AGAL Accession No. NM 00/09624), was cultured for two days at 25°C in 100 ml of sterile (autoclaved) pontiac broth (potatoes 400g/l), comprising either 2% (w/v) glucose, or 4% (w/v) glucose, or 4% (w/v) galactose, or 4% 25 (w/v) mannose as a carbon source. The identities of the sugar acids produced were determined using mass spectrum as described in the preceding Examples.

Mass spectrum analysis of active fractions indicated that, in each sample, there is only one sugar acid produced which corresponds to the aldonic acid product of the aldose 30 sugar substrate provided to the bacterial cultures grown under these conditions. In particular, glucose was converted to gluconic acid (i.e. the peak for gluconic acid was

- 71 -

as in Figure 5D), galactose was converted to galactonic acid (the peak for galactonic acid was as in Figure 11B), and mannose was converted to mannonic acid (the peak for mannonic acid was as in Figure 12B).

5

**TABLE 4****Comparison of genetically engineered strains**

Bacterial Treatment	Bacteria (cells/ gram wheat root)	Take-all disease score	Plant dry weight (% of control plant)
1. Control (no take-all or bacteria)	0	0	100%
2. Take-all treatment (no bacteria)	0	5	9%
3. <i>Pseudomonas</i> strain AN5	$8 \times 10^7$	2	78%
4. <i>Pseudomonas</i> strain AN5-M1	$1 \times 10^3$	2	83%
5. <i>Pseudomonas</i> strain AN5-P1	$8 \times 10^5$	1	93%
6. <i>Pseudomonas</i> strain AN5-T5	$5 \times 10^7$	1	95%

20

T0520T 90E06860

**EXAMPLE 11****Quantitation of gluconic acid produced by *Pseudomonas* strain AN5 rif cultures using glucose as the sole carbon source****1. Quantitation of sugar acids produced by *Pseudomonas* sp. strain AN5 rif**

5 *Pseudomonas* strain AN5 rif (AGAL Accession No. NM 00/09624), was cultured for two days at 25°C in 100 ml of sterile (autoclaved) pontiac broth (potatoes 400g/l), comprising either 2% (w/v) glucose, or 4% (w/v) glucose, or 2% (w/v) galactose, or 4% (w/v) galactose. A negative control solution was also prepared which contained no additional aldose substrate. Sugars were added from stock solutions sterilised by the  
10 addition of chloroform.

The total numbers of viable cells were determined after two days of culture, using standard procedures. The viable count for cultures containing 2% (w/v) glucose in pontiac broth were, on average  $7.325 \times 10^7$  cells/ml, compared to only  $6.0 \times 10^4$  cell/ml  
15 for cultures grown on pontiac broth without added sugar.

The pH values of the culture supernatants were determined following collection of the bacterial cells after two days of culture, by centrifugation at 6,000 rpm to collect bacterial cells, and titration of an aliquot of each supernatant against 0.001N to 0.01N  
20 NaOH. To confirm the titrable pH value obtained for each supernatant, equal volumes of acetone were added to the remaining supernatants, and samples incubated overnight at 4°C to precipitate any proteinaceous components or bacterial cells. The precipitates were removed by centrifugation at 6,000 rpm and the pH values of the culture supernatants determined by titration as before. Results were as follows:

- |   |                       |
|---|-----------------------|
| 25 Bacteria cultured with 2% (w/v) glucose: | pH = 8.0 (8.8**);     |
| Bacteria cultured with 4% (w/v) glucose:    | pH = 7.9 (8.5**);     |
| Bacteria cultured with 2% (w/v) galactose:  | pH = 8.2 (8.8**);     |
| Bacteria cultured with 4% (w/v) galactose:  | pH = 7.9 (8.3**);     |
| Bacteria cultured without sugar:            | pH = 9.0 (9.6**); and |
| 30 Pontiac broth alone:                     | pH = 6.5.             |

\*\* : pH values in parentheses indicate the pH of supernatants following acetone

- 73 -

precipitation.

Pontiac broth comprising 2% (w/v) galactose produced a magenta (dark pink) colour using the indicator dye phenolphthalein, and, as a consequence, that medium was not  
 5 titratable using sodium hydroxide solution. Other media required small volumes of 0.001N sodium hydroxide to produce the same pink colour as that which was produced for pontiac broth inoculated with *Pseudomonas* strain AN5 *rif* (AGAL Accession No. NM 00/09624) in the absence of aldose. The average amount of 0.001N NaOH required to neutralize acid sugars produced by each 100 ml culture (n = 3), was as  
 10 follows:

Bacteria cultured with 2% (w/v) glucose:	0.6 ml;
Bacteria cultured with 4% (w/v) glucose:	0.8 ml;
Bacteria cultured with 2% (w/v) galactose:	nd **;
15 Bacteria cultured with 4% (w/v) mannose:	0.45 ml; and
Bacteria cultured without sugar:	0.0 ml.
(**: not determined)	

For solid media, pontiac agar plates were prepared and adjusted to pH values of 6.5,  
 20 8.5 , 10.5, and 12.5. Bromocresol purple (15mg/ l) was added to each plate. Pontiac agar plates were inoculated by streaking *Pseudomonas* strain AN5 *rif* (AGAL Accession No. NM 00/09624), and incubated for one day at 25°C. After this period, those plates which were at a pH in the range of pH 6.5 to pH 10.5 began to turn yellow. However, no colour change was apparent for those plates at pH 12.5. Bacterial growth  
 25 was also affected by the pH of the culture media, and more growth was observed at lower pH values, in the order: 6.5=8.5 > 10.5 > 12.5. Growth was very poor at pH 12.5.

In summary, titration of bacterial cultures is not the optimum method for the quantitation of sugar acids, wherein the carbon source is other than glucose, because  
 30 of the high alkaline pH of the solution which is required for bacterial growth. However, this method is preferred for use in conjunction with solid media. Alternatively, sugars



- 74 -

are quantitated using the procedure described in the following citation: *Microbiology* 143: 1595-1603, 1997.

2. Assay of gluconic acid production by *Pseudomonas* strain AN5 rif

- 5 *Pseudomonas* strain AN5 rif (AGAL Accession No. NM 00/09624) was streaked onto nutrient agar containing rifampicin (100ug/ml) and incubated at 25°C for two days. From these plates, nutrient broth and pontiac broth were inoculated with a bacterial loop. These broths were also incubated at 25°C on a shaker for two days. 5ml of these broths was used to inoculate 100ml of respective broths. These were grown overnight
- 10 for about 15-18 hour. Small aliquot's of these were used with a number of dilutions to obtain viable cell counts. These cultures were centrifuged at 6000rpm for 15 minutes to pellet cells. The bacterial pellets were washed twice with distilled autoclaved water to remove any broth, and resuspended in 100ml 0.01M glucose solution (pH 7 glucose at 1.8 g/l). Bacterial suspensions were incubated on shaker at 25°C. After 3.5h, these
- 15 solutions were observed to produce a yellow colour in the presence of bromocresol purple (15mg/ l). Supernatant's were frozen at -30°C and then lyophilised. An aliquot of the lyophilised material was dissolved in water, and 5ml of solution was titrated with 0.01N NaOH. Sugar acids were quantitated as described above.
- 20 Data indicate that bacteria obtained from pontiac broth as a starter culture and then grown in pure glucose solution are capable of converting 40% of the glucose substrate present to gluconic acid in 3.5 hour under these conditions. In nutrient broth as a starter culture in a similar experiment, 32% of the glucose substrate was converted to gluconic acid in same time. These results suggest that pontiac broth is better medium
- 25 for starter culture of bacteria for the production of gluconic acid, when glucose is used as a sole carbon source.

- 75 -

**EXAMPLE 12****Summary of sugar acid production by different *Pseudomonas* strains  
on different carbon sources**

The levels of sugar acids produced by *Pseudomonas* strain AN5 *rif* (AGAL Accession  
5 No. NM 00/09624), and the two transposon mutants, PQQ<sup>-</sup> and SOX<sup>-</sup>, carrying the  
Tn5:*uidA* transposon in the *pqqD* and sugar oxidase genes (Example 9), were  
determined following growth in pontiac media, with or without 2% (w/v) aldose in the  
culture medium. Data are presented in Table 5.

**TABLE 5**

<b>Bacterial strain</b>	<b>added sugar</b>	<b>Time (hr)</b>	<b>Culture O.D.</b>	<b>media pH</b>	<b>sugar acid (mg/ml)</b>
PQQ-	none	17	240	7.0-8.3	0.00
	glucose	63	410	5.95	0.117
SOX-	none	17	232	7.0-8.3	0.00
	glucose	63	380	5.9	0.117
AN5 <i>rif</i>	none	17	212	6.1-8.6	0.00
	glucose	47	450	2.95	5.10
	glucose	64	305	3.0	5.10
	none	23	235	8.6	0.00
	galactose	47	435	3.35	1.61
	galactose	70	390	3.1	2.24
	none	23	235	6.1-8.6	0.00
	mannose	70	380	3.25	3.92

Data are consistent with glucose being the preferred carbon source for *Pseudomonas*  
strain AN5 and derivatives thereof to produce sugar acids from aldose substrate.

- 76 -

**EXAMPLE 13****Production of anti-fungal effective amounts of sugar acids *in situ* on wheat roots by *Pseudomonas* strain AN5**

Wheat seeds were treated with various biocontrol bacteria and grown in sterile  
5 magenta jar assays in vermiculite. We collected the root exudate of wheat roots  
inoculated with these various biocontrol strains. These included the parent strain (i.e.  
*Pseudomonas* strain AN5), *Pseudomonas* strain AN5 *rif* (AGAL Accession No. NM  
00/09624), and various mutants, including the PQQ- and SOX- mutants. The exudate  
were concentrated by freeze drying and then resuspended in water. Only  
10 *Pseudomonas* strain AN5. and *Pseudomonas* strain AN5*rif* showed strong biological  
activity in bioassays against the take-all pathogen. The extracts from the remaining  
mutant strains, or untreated wheat, showed no biological activity. These data suggest  
that the sugar acid is produced by *Pseudomonas* strain AN5, or *Pseudomonas* strain  
AN5*rif* (AGAL Accession No. NM 00/09624), on wheat roots, in suppression of the  
15 take-all pathogen on wheat roots.

**EXAMPLE 14****Isolation of nucleotide sequences of *Pseudomonas* sp. encoding  
20 PQQ-dependent sugar oxidases and PQQ-biosynthesis genes**

To identify the gene region of *Pseudomonas* sp. which encodes genes for the  
production of sugar acids, mutant lines were produced by transposon mutagenesis  
using a Tn5:*uidA* transposon. Two mutant lines were identified which failed to confer  
protection against take-all fungus in bioassays.

25

Restriction enzyme fragments (e.g. *Bam*H1, *Hind* III, *Eco*R 1) were produced from  
these mutant lines. Mapping and sequence analyses of the cloned fragments indicated  
that the transposon was inserted into two non-contiguous regions of the genome, as  
follows:

- 30 1. a first region encoding the enzymes involved in catalysing the conversion of  
aldose to sugar acid, the partial sequence of which is set forth in SEQ ID NO: 1; and

- 77 -

2. a second region encoding the enzymes required for the synthesis of the cofactor, PQQ, the partial sequence of which is presented in SEQ ID NO: 4.

Limited homology of the nucleotide sequence set forth in SEQ ID NO: 1 to bacterial  
5 dehydrogenases suggests that this sequence encodes an enzyme involved in sugar metabolism.

Nucleotide sequence analysis also indicated that the transposon was inserted into the pqqD gene of the second region. In particular, an alignment of the pqqD gene of  
10 *Pseudomonas* strain AN5, with the pqqD genes of other bacteria, indicating limited identity (not shown). These data indicated that this tagged region of the *Pseudomonas* sp. genome comprises the PQQ operon.

Southern blot hybridisation mapping analyses indicate that the sugar oxidase gene of  
15 *Pseudomonas* strain AN5 is contained on the following DNA fragments: a 3.8 kb *Bam*HI fragment; a 7.6 kb *Bgl*II fragment; a 6.5 kb *Pst*I fragment; an approximately 18 kb *Hind*III fragment; and an approximately 22 kb *Eco*RI fragment.

Southern blot hybridisation mapping analyses indicate that the PQQ operon oxidase  
20 gene of *Pseudomonas* strain AN5 is contained on the following DNA fragments: an approximately 20 kb *Bam*HI fragment; an 8.0 kb *Pst*I fragment; an approximately 18 kb *Hind*III fragment; and an approximately 20 kb *Eco*RI fragment.

The appropriate genomic regions were isolated from *Pseudomonas* strain AN5, which  
25 possesses anti-fungal activity, and cloned into the cosmid vector pLAF3, to produce the following cosmid clones:

1. Cosmid pMN M53 (AGAL Accession No. NM 00/09622), comprising 30-40 kb of *Pseudomonas* strain AN5 DNA which comprises nucleotide sequences encoding a sugar oxidase enzyme; and
- 30 2. Cosmid pMN-L2 (AGAL Accession No. NM 00/09621), comprising 30-40 kb of *Pseudomonas* strain AN5 DNA which comprises nucleotide sequences of the PQQ

- 78 -

operon.

The nucleotide sequences of the various genes of the PQQ operon were determined, and are set forth in SEQ ID NOs: 2 to 6. Mapping data presented in Figure 13 indicate the relative arrangement of the genes of the PQQ operon of *Pseudomonas sp.* compared to other bacteria.

## REFERENCES

1. Amann and Brosius (1985). *Gene* **40**: 183.
2. An, et al. (1985) *EMBO J.* **4**:277-284.
3. Armstrong, et al.(1990) *Plant Cell Rep.* **9**: 335-339.
4. Aszalos, A., et al. (1968) *J. Chromatography* **37**: 487-498.
5. Ausubel, et al. (1987) *In: Curr.Protocol.Mol.Biol.* Wiley Interscience.
6. Baker, K. F.et al (1974) *Biol. control plant pathogens*, W.H.Freeman and Co., USA.
7. Buyer, J. S. et al. (1986) *J. Biol. Chem.* **261**: 791-794.
8. Christou, et al. (1988) *Plant Physiol.* **87**: 671-674.
9. Crossway, et al. (1986) *Mol. Gen. Genet.* **202**:179-185.
10. Devereux, J., et al. (1984) *Nucl. Acids Res.* **12**: 387-395.
11. Fravel, D. R. (1988) *Ann. Rev. Phytopathol.* **26**: 75-91.
12. Gal A.E. (1968) *Anal. Biochem.* **24**: 452-461.
13. Gennaro, A. R. (1990) *In: Remington's Pharmaceutical Sciences*, 18th edition, Mack Publishing Company, Easton, Pennsylvania 18042, USA, pp 1266-1268.
14. Ghebregzabher, et al. (1976) *J. Chrom.* **127**: 133-162.
15. Gurusiddaiah S., et al.(1986) *Antimicrob. Agent. Chemother.* **29**: 488-495.
16. Hamdan, H., et al. (1991) *App. Environ. Microbiol.* **57**: 3270-3277.
17. Fromm, et al. (1985) *Proc. Natl. Acad. Sci. (USA)* **82**: 5824-5828.
18. Hanahan (1983) \_\_\_\_\_
19. Herrera-Estella et al. (1983a) *Nature* **303**: 209-213.
20. Herrera-Estella et al. (1983b) *EMBO J.* **2**: 987-995.

21. Herrera-Estella *et al.* (1985) *In: Plant Genetic Engineering*, Cambridge University Press, N.Y., pp 63-93.
22. Huynh *et al.* (1985) *In: DNA Cloning Vol. I: A Practical Approach* (ed, D.M. Glover), IRL Press Limited, Oxford. pp49-78.
- 5 23. Keel C, *et al.* (1992) *Mol. Plant-Microb. Interact.* 5: 4-13.
24. Keel C, *et al.* (1996) *App. Environ. Microbiol.* 62: 552-63.
25. Kim *et al.* (1988) *Phytopathol.* 78: 488-492.
26. Kim *et al.* (1990) *Can J. Microbiol.* 36: 199-205.
27. Kirk-Othmer, *et al.* (1980) *In: Encyclopedia of Chemical Technology*, Third Edition, Vol. 11 (eds: H.F. Mark; D. F. Othmer; C. G. Overberger; G. T. Seaborg; M. Grayson; and D. Eckroth) John Wiley & Sons, New York, pp 490-498.
- 10 28. Kloepper, J. W., *et al.* (1980) *Nature* 286: 885-886.
29. Kraus *et al.* (1992) *Phytopathol.* 82: 264-271.
- 15 30. Krens, *et al.* (1982) *Nature* 296: 72-74.
31. Laville, J., *et al.* (1992) *Proc. Nat. Acad. Sci. USA* 89: 1563 -1566.
32. Leong, J. (1986). *Ann. Rev. Phytopathol.* 24: 187-209.
33. McPherson, M.J., *et al.* (1991) *PCR A Practical Approach*. IRL Press, Oxford University Press, Oxford, United Kingdom.
- 20 34. Murray, G. M., Brown, J. F. (1987) *Aust. Plant Pathol.* 16: 34-37.
35. Murray, F.R. *et al.* (1997) *Curr. Genet.* 32: 367-375.
36. Nayudu, M., Holloway, B.W. (1981) *Plasmid* 6: 53-66.
37. Nayudu, M., Rolfe, B.G. (1987) *Mol. Gen. Genet.* 206: 326-337.
38. Nayudu, M., *et al.* (1994a) *In: Curr. topics Mol. Genet.* (ed, S.G. Pandalai, Council of Scientific Integration), pp127-150.
- 25 39. Nayudu, M., *et al.* (1994b) *In: Plant Growth Promoting Bacteria.* (eds, M. Ryder, P.M. Stephens, and G.D. Bowen) pp 122-124.
40. Needleman and Wunsch (1970) *J. Mol. Biol.* 48: 443-453.
41. Paszkowski, *et al.* (1984) *EMBO J.* 3: 2717-2722.
- 30 42. Pfender WF, *et al.* (1993) *Phytopathol.* 83: 1223-1228.
43. Poplawsky, A.R., *et al.* (1988) *Phytopathol.* 78: 426-432.

44. Raaijmakers, J.M., et al. (1998) *Mol. Plant Mic. Interact.* 11:144-152.
45. Rosales AM, et al. (1995) *Phytopathol.* 85:1028-1032.
46. Sanford, J.C., et al. (1988) *Part. Sci.Technol.* 5: 27-37.
47. Schroth, M. N. et al.(1981). *Ann. Rev. Microbiol.* 35: 453-476.
- 5 48. Shimatake and Rosenberg (1981) *Nature* 292: 128.
49. Still W.C., et al.(1978) *J. Org. Chem.* 43: 2923- 2925.
50. Stosz et al., (1996) *App. Environ. Microbiol.* 62: 3183-3186.
51. Studier and Moffat (1986) *J. Mol. Biol.* 189: 113.
52. Suslow, T. V. (1982). In: *Phytopathogenic Prokaryotes*, (eds, M. S. Mount, and  
10 G. H. Lacey), Academic Press, London, pp 187-223.
53. Thomashow, L.S., et al. (1990) *Appl. Environ. Biol.* 56: 908-912.
54. Thomashow, L.S., et al. (1993) In: *Mol. Genet. Plant Microbe Interact.*, Kluwer  
Academic Publishers, pp 535-641.
55. Thompson,et al. (1994) *Nucl. Acids Res.* 22: 4673-4680.
- 15 56. Weller, D. M. (1988) *Ann. Rev. Phytopathol.* 26: 379-407.
57. Weller, D. M., et al.(1983). *Phytopathol.* 73: 463-469.
58. Wong, P.T.W., et al.(1996) *Plant Pathology* 45: 285-293.
59. Wu, et al., (1995) *The Plant Cell* 7: 1357-1368.a)

- 81 -

## CLAIMS:

1. A method of prophylactic or therapeutic treatment of fungal infection in an animal or non-aquatic plant comprising administering a sugar acid other than as a metal salt in an amount sufficient to inhibit or prevent fungal growth or reproduction in said animal or non-aquatic plant, wherein said sugar acid in an isolated form or in the form of a biocontrol agent other than *Pseudomonas sp.* strain AN5.
2. The method according to claim 1 wherein the fungal pathogen is selected from the group consisting of: *Alternaria spp.*; *Armillaria melleae*; *Arthrobotrys oligosporus*; *Boletus granulatus*; *Botrytis fabae*; *Botritis cinerea*; *Candida albicans*; *Claviceps purpurea*; *Cronartium ribicola*; *Epicoccum purpurescens*; *Epidermophyton floccosum*; *Fomes annosus*; *Fusarium oxysporum*; *Gaeumannomyces graminis var. tritici*; *Glomerella cingulata*; *Gymnosporangium juniperi-virginianae*; *Microsporum canis*; *Monilinia fructicola*; *Physoderma alfalfae*; *Phytopthera infestans*; *Pityrosporum orbiculare (Malassezia furfur)*; *Polyporus sulphureus*; *Puccinia spp.*; *Saccharomyces cerevisiae*; *Septoria apiicola*; *Trichophyton rubrum*; *T. mentagrophytes*; *Ustilago spp.*; *Venturia inaequalis*; and *Verticillium dahliae*.
3. The method according to claim 1 or 2 wherein the fungal pathogen is *G. graminis* (take-all fungus).
4. The method according to claim 1 or 2 wherein the fungal pathogen is *Botrytis fabae*.
5. The method according to any one of claims 1 to 4 wherein the sugar acid is selected from the group consisting of mannonic acid, gluconic acid, and galacturonic acid.
6. The method according to claim 5 wherein the sugar acid is gluconic acid.



- 82 -

7. The method according to any one of claims 1 to 6 wherein the sugar acid is administered in pure or partially-purified form.
8. The method according to any one of claims 1 to 6 wherein the biocontrol agent is capable of producing an anti-fungal effective amount of the sugar acid when incubated in media containing an aldose substrate.
9. The method according to claim 8 wherein the biocontrol agent is a bacterial cell.
10. The method of claim 9 wherein the bacterial cell belongs to the genus *Pseudomonas*.
11. The method of claim 10 wherein the *Pseudomonas* has the capacity to convert aldose to sugar acid in a PQQ-dependent manner.
12. The method of claim 11 wherein the *Pseudomonas* has the sugar acid biosynthesis characteristics of the bacterial strain deposited under AGAL Accession No. NM 00/09624.
13. The method of claim 12 wherein the *Pseudomonas* is strain AN5rif (AGAL Accession No. NM 00/09624).
14. A method of increasing the post-harvest storage of a product from a non-aquatic plant comprising applying to said product a sugar acid other than as a metal salt in an amount sufficient to inhibit or prevent fungal growth or reproduction, wherein said sugar acid in an isolated form or in the form of a biocontrol agent other than *Pseudomonas sp.* strain AN5.

- 83 -

15. The method according to claim 14 wherein the sugar acid is selected from the group consisting of mannonic acid, gluconic acid, and galacturonic acid.
16. The method according to claim 15 wherein the sugar acid is gluconic acid.
17. The method according to any one of claims 14 to 16 wherein the sugar acid is administered in pure or partially-purified form.
18. The method according to any one of claims 14 to 16 wherein the biocontrol agent is capable of producing an anti-fungal effective amount of the sugar acid when incubated in media containing an aldose substrate.
19. The method according to claim 18 wherein the biocontrol agent is a bacterial cell.
20. The method of claim 19 wherein the bacterial cell belongs to the genus *Pseudomonas*.
21. The method of claim 20 wherein the *Pseudomonas* has the capacity to convert aldose to sugar acid in a PQQ-dependent manner.
22. The method of claim 21 wherein the *Pseudomonas* has the sugar acid biosynthesis characteristics of the bacterial strain deposited under AGAL Accession No. NM 00/09624.
23. The method of claim 22 wherein the *Pseudomonas* is strain AN5rif (AGAL Accession No. NM 00/09624).

- 84 -

24. An isolated biocontrol agent for the treatment of a fungal infection in a plant or animal, said agent comprising a bacterial cell other than *Pseudomonas* strain AN5 having the following characteristics:

- (i) it produces a sugar acid when cultured in the presence of a carbon source comprising an aldose;
- (ii) it is capable of colonizing the infection site of said fungus; and
- (iii) it has the biocontrol properties of *Pseudomonas* strain AN5 *rif* (AGAL Accession No. NM 00/09624).

25. The biocontrol agent according to claim 24 comprising *Pseudomonas* strain AN5*rif* (AGAL Accession No. NM 00/09624) or a derivative thereof.

26. The biocontrol agent according to claim 25 wherein the derivative has enhanced capacity compared to *Pseudomonas* strain AN5*rif* to produce a sugar acid when cultured in the presence of a carbon source comprising an aldose.

27. The biocontrol agent according to claim 25 or 26 wherein the derivative has enhanced capacity compared to *Pseudomonas* strain AN5*rif* to colonize the rhizosphere of a plant.

28. A phytoprotective composition for the treatment of a fungal infection of a non-aquatic plant comprising an effective amount of a sugar acid in combination with a phytopathologically-acceptable diluent or wetting agent, wherein said sugar acid is in a form other than a metal salt.

29. The phytoprotective composition according to claim 28, wherein the sugar acid is selected from the group consisting of mannonic acid, gluconic acid, and galacturonic acid.

30. The phytoprotective composition according to claim 29, wherein the sugar acid is gluconic acid.

- 85 -

31. A phytoprotective composition for the treatment of a fungal infection of a plant comprising the biocontrol agent according to any one of claims 24 to 27 in combination with a phytopathologically-acceptable diluent or wetting agent.
32. The phytoprotective composition according to any one of claims 28 to 31 wherein the wetting agent is a non-ionic detergent.
33. The phytoprotective composition according to any one of claims 28 to 32, wherein the fungal infection is an infection by a fungal pathogen selected from the group consisting of *Alternaria spp.*; *A. mellae*; *A. oligosporus*; *B. granulatus*; *B. cinerea*; *Botrytis fabae*; *C. purpurea*; *C. ribicola*; *E. purpurescens*; *F. annosus*; *F. oxysporum*; *G. graminis* var. *tritici*; *G. cingulata*; *G. juniperi-virginianae*; *M. fructicola*; *P. alfalfae*; *P. infestans*; *P. sulphureus*; *Puccinia spp.*; *S. apiicola*; *Ustilago spp.*; *V. inaequalis*; and *V. dahliae*; and still more preferably, a fungal pathogen of monocotyledonous plants selected from the group consisting of *C. purpurea*; *G. graminis* var *tritici*; *Puccinia spp.*; and *Ustilago spp.*.
34. The phytoprotective composition according to claim 33 wherein the fungal pathogen is *G. graminis* (take-all fungus).
35. The phytoprotective composition according to claim 34 wherein the fungal pathogen is *Botrytis fabae*.
36. A composition for the treatment of a fungal infection in a human or other mammal comprising an effective amount of a sugar acid in combination with one or more pharmaceutically-acceptable carriers or diluents, wherein said sugar acid is in a form other than a metal salt.
37. The composition according to claim 36 wherein the sugar acid is selected from the group consisting of mannonic acid, gluconic acid, and galacturonic acid.

- 86 -

38. The composition according to claim 37, wherein the sugar acid is gluconic acid.

39. A composition for the treatment of a fungal infection in a human or other mammal comprising the biocontrol agent according to any one of claims 24 to 26 in combination with one or more pharmaceutically-acceptable carriers or diluents.

40. The composition according to any one of claims 36 to 39 for the treatment of a condition selected from the group consisting of tinea pedis (athlete's foot), tinea cruris, tinea corporis (ringworm), candidiasis, onychia, paronychia, external genital candidiasis, candidal balanitis, pityriasis versicolor and jockey-strap itch.

41. A method of producing a sugar acid comprising incubating a bacterial cell having the biocontrol properties of *Pseudomonas* strain AN5 *rif* (AGAL Accession No. NM 00/09624) in the presence of aldose for a time and under conditions sufficient for PQQ-dependent oxidation of the aldose to sugar acid to occur, wherein said bacterial cell is not *Pseudomonas* strain AN5.

42. The method according to claim 41 wherein the bacterial strain is *Pseudomonas* strain AN5 *rif* (AGAL Accession No. NM 00/09624).

43. The method according to claim 41 or 42 wherein the aldose is selected from the group consisting of glucose, mannose and galactose.

44. The method according to claim 43 wherein the aldose is glucose.

45. The method according to any one of claims 41 to 44 wherein the culture conditions comprise growth on potato dextrose media or pontiac medium containing aldose substrate.

- 87 -

46. The method according to claim 45 wherein the aldose substrate is at about 2% (w/v) to about 4% (w/v) in the culture medium.

47. The method according to any one of claims 41 to 44 wherein the culture conditions comprise growth on potato dextrose media or pontiac medium followed by incubation in a concentrated solution of aldose substrate.

48. An isolated nucleic acid molecule which comprises a nucleotide sequence which encodes one or more enzymes involved in the biosynthesis of a sugar acid, wherein said nucleotide sequence is selected from the group consisting of:

- (i) a nucleotide sequence which is at least about 50% identical to at least about 30 contiguous nucleotides of SEQ ID NO: 1 or a complementary sequence thereto;
- (ii) a nucleotide sequence which is at least about 50% identical to at least about 30 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622);
- (iii) a nucleotide sequence which is capable of hybridising under at least low stringency conditions to at least about 30 contiguous nucleotides of SEQ ID NO: 1 or a complementary sequence thereto;
- (vi) a nucleotide sequence which is capable of hybridising under at least low stringency conditions to at least about 30 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622); and
- (vii) a nucleotide sequence which is degenerate to SEQ ID NO: 1 or the *Pseudomonas* gene sequence contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622).

- 88 -

49. The isolated nucleic acid molecule of claim 48 wherein the nucleotide sequence encodes a sugar oxidase enzyme.

50. The isolated nucleic acid molecule of claim 49 wherein the sugar oxidase enzyme is a PQQ-dependent sugar oxidase enzyme.

51. The isolated nucleic acid molecule according to any one of claims 48 to 50 comprising the nucleotide sequence of SEQ ID NO: 1.

52. The isolated nucleic acid molecule according to any one of claims 48 to 51 comprising the nucleotide sequence of the *Pseudomonas* genome contained in the cosmid clone pMN M53 (AGAL Accession No. NM 00/09622).

53. An isolated nucleic acid molecule comprising a nucleotide sequence encoding one or more enzymes involved in the biosynthesis of PQQ, wherein said nucleotide sequence is selected from the group consisting of:

- (i) a nucleotide sequence having at least about 50 contiguous nucleotides of any one of SEQ ID NOs: 2 to 6 or a complementary sequence thereto;
- (ii) a nucleotide sequence having at least about 50 contiguous nucleotides of the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621); and
- (iii) a nucleotide sequence that is degenerate to any one of SEQ ID NOs: 2 to 6 or the *Pseudomonas* gene sequence contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621).

54. The isolated nucleic acid molecule according to claim 53 comprising the nucleotide sequence of SEQ ID NO: 2.

55. The isolated nucleic acid molecule according to claim 53 comprising the nucleotide sequence of SEQ ID NO: 3.

AMENDED SHEET  
IPEA/AU

09590306 102501

- 89 -

56. The isolated nucleic acid molecule according to claim 53 comprising the nucleotide sequence of SEQ ID NO: 4.

57. The isolated nucleic acid molecule according to claim 53 comprising the nucleotide sequence of SEQ ID NO: 5.

58. The isolated nucleic acid molecule according to claim 53 comprising the nucleotide sequence of SEQ ID NO: 6.

59. The isolated nucleic acid molecule according to any one of claims 53 to 58 comprising the nucleotide sequence of the *Pseudomonas* genome contained in the cosmid clone pMN-L2 (AGAL Accession No. NM 00/09621).

60. A method of producing a sugar acid comprising expressing the isolated nucleic acid molecule according to any one of claims 48 to 52 in a cell, tissue or organism and culturing said cell, tissue or organism in the presence of an aldose substrate for a time and under conditions sufficient to produce a sugar acid.

61. The method according to claim 60 further comprising introducing the nucleic acid molecule to the cell, tissue or organ in an expressible format.

62. The method according to claim 60 or 61 further comprising extracting or purifying the sugar acid produced.

63. The method according to any one of claims 60 to 62 wherein the cell is a bacterial cell.

64. The method according to claim 63 wherein the bacterial cell is a *Pseudomonas* sp.



- 90 -

65. The method according to any one of claims 60 to 62 wherein the cell, tissue or organ is a plant cell, tissue, or organ.

66. The method according to any one of claims 60 to 65 further comprising expressing the nucleic acid molecule according to any one of claims 53 to 59 for a time and under conditions sufficient to produce PQQ in the cell, tissue or organ.

67. A method of enhancing the tolerance of a plant to infection by a fungal pathogen comprising expressing therein the isolated nucleic acid molecule according to any one of claims 48 to 52, and optionally a second isolated nucleic acid molecule encoding one or more PQQ-biosynthesis enzymes, for a time and under conditions sufficient for a sugar acid to be produced by said plant, or by a cell, tissue or organ of said plant.

68. The method according to claim 67 wherein the second isolated nucleic acid molecule is the nucleic acid molecule according to any one of claims 53 to 59.

69. A transformed plant comprising the isolated nucleic acid molecule according to any one of claims 48 to 59.

70. A progeny plant, cell, tissue or organ of the plant according to claim 69, wherein said progeny, cell, tissue or organ comprises the isolated nucleic acid molecule according to any one of claims 48 to 59.

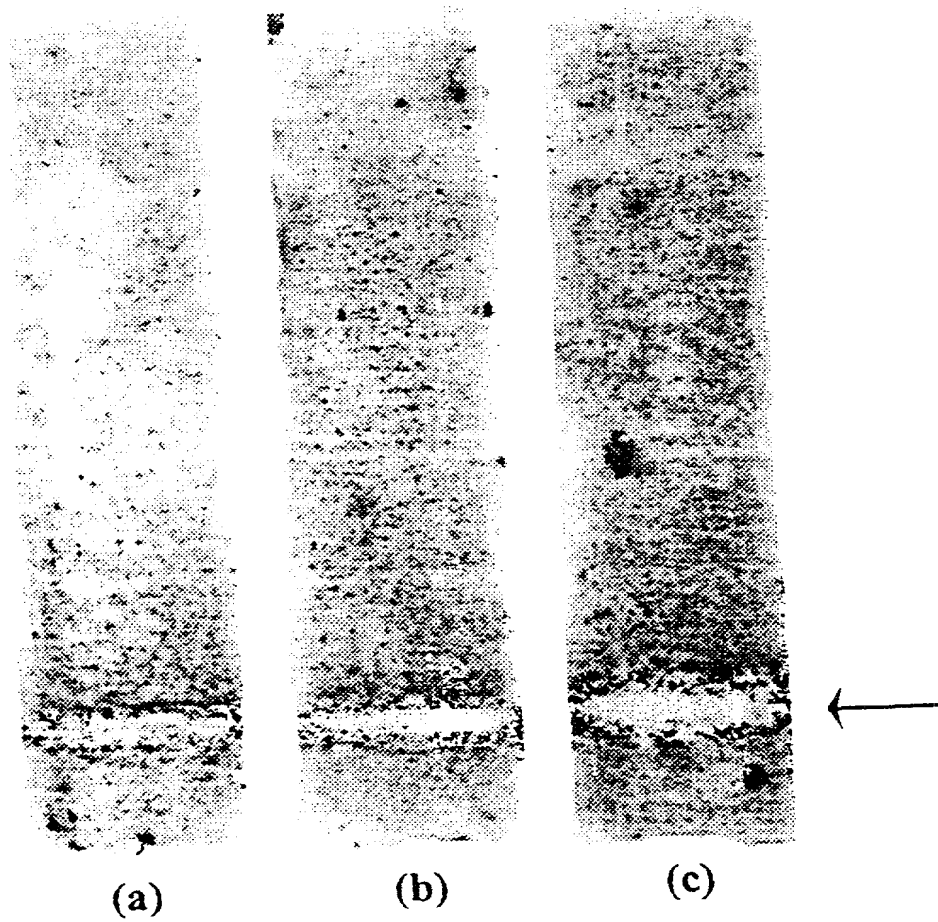
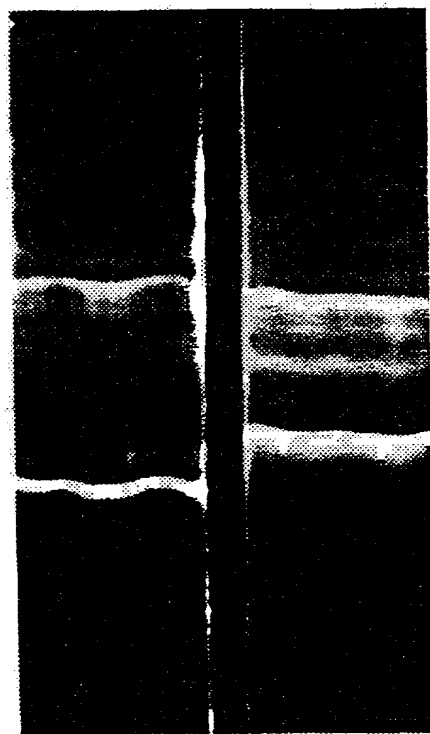


FIGURE 1



(a)

(b)

FIGURE 2A

T0520T" 90E06860

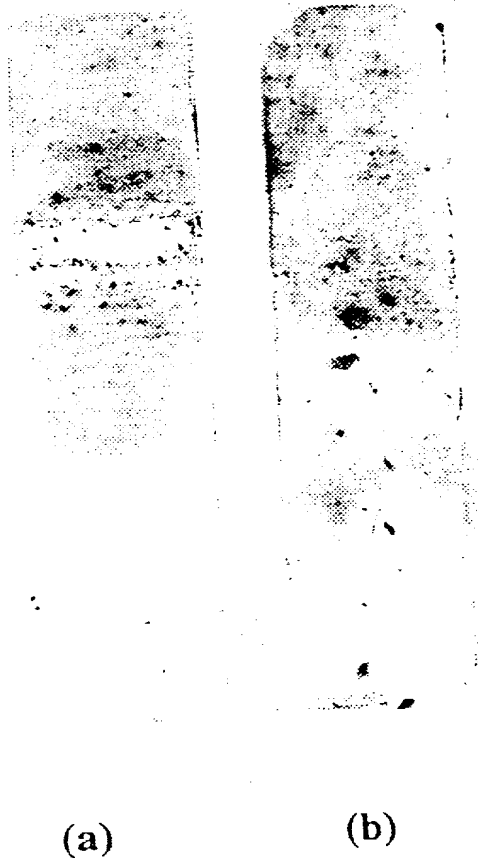
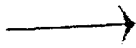


FIGURE 2B

Test "90E06860"

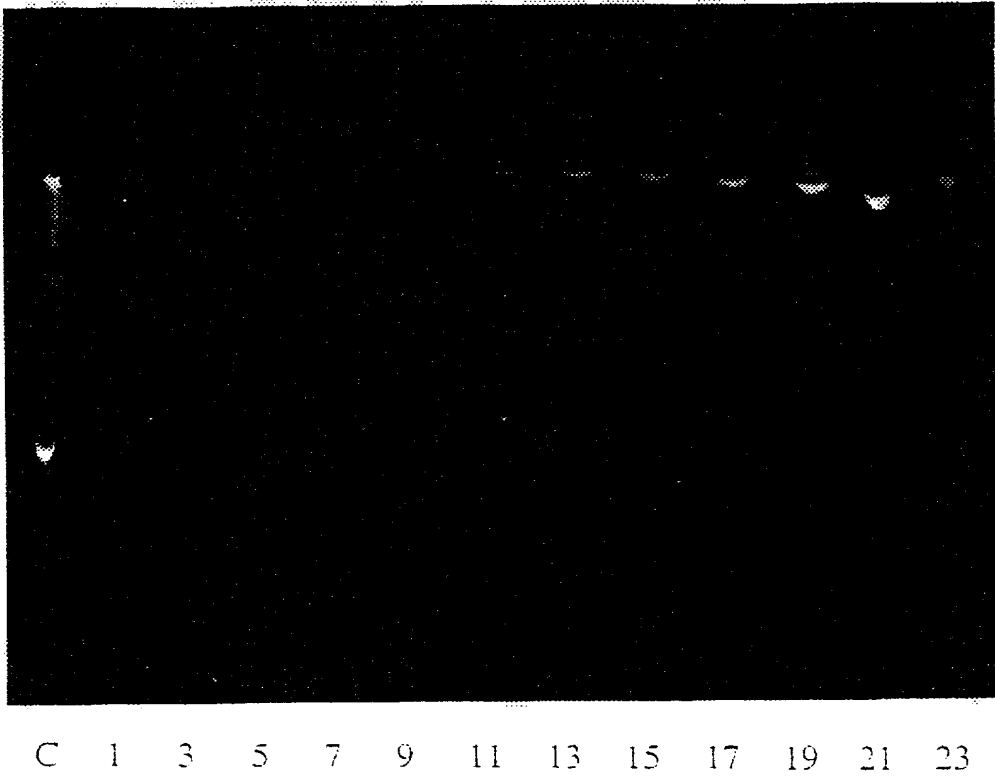


FIGURE 3A

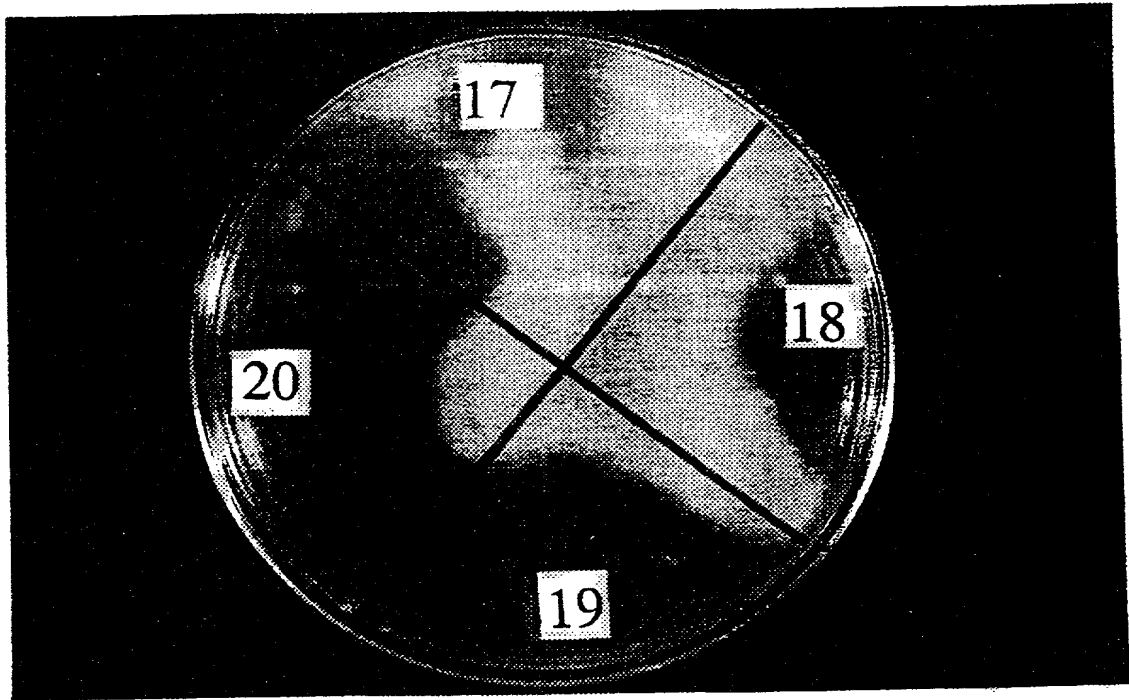


FIGURE 3B

6/23

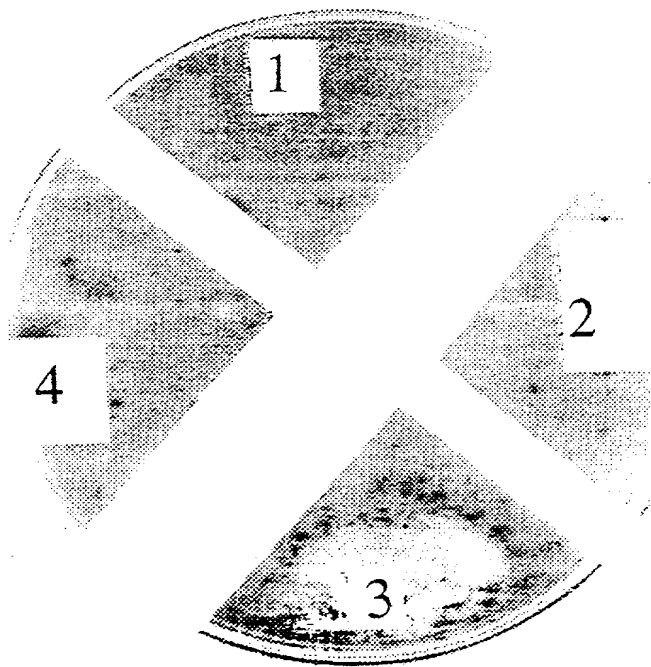


FIGURE 4

09890306 10501 T0520T" 90E06860

7/23

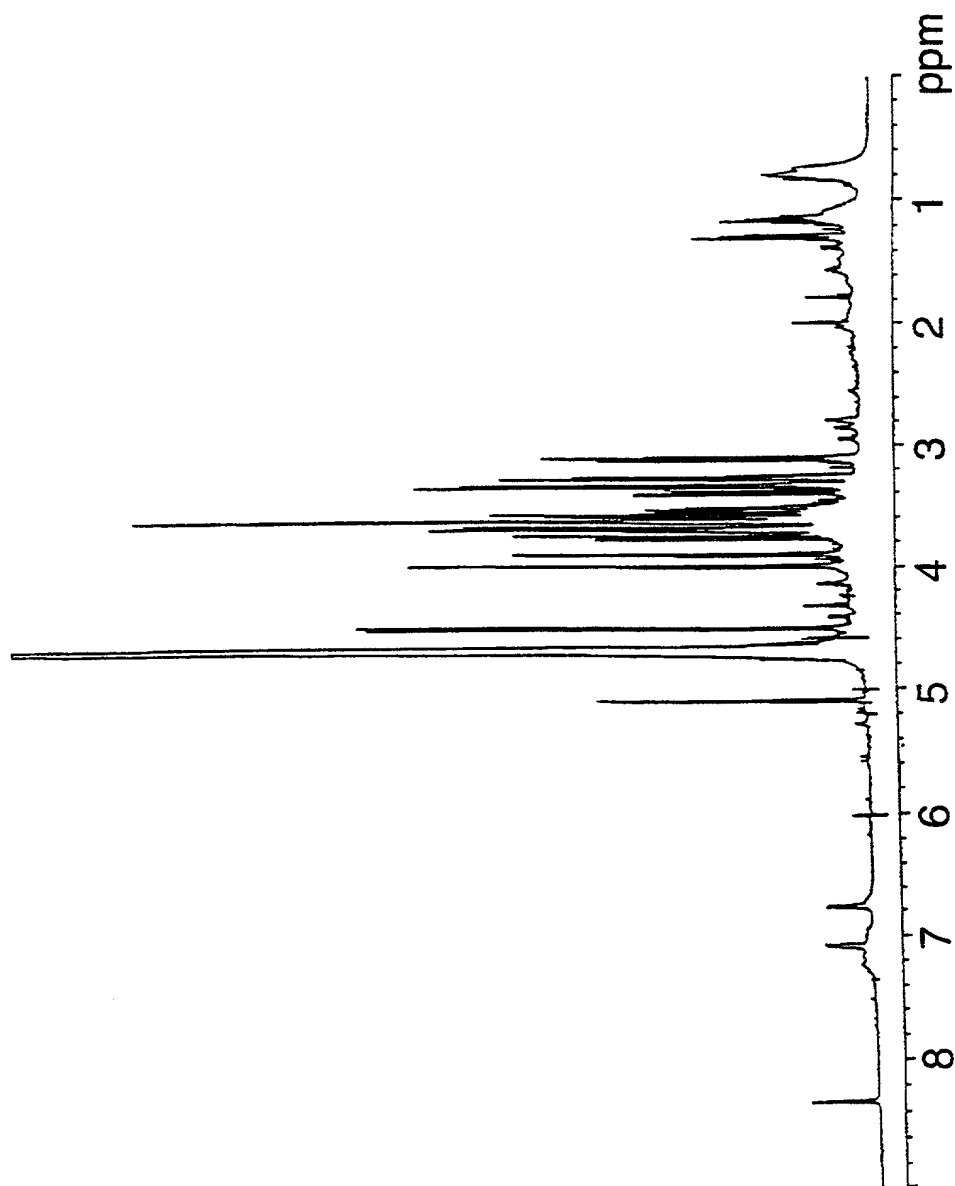


Figure 5a



8/23

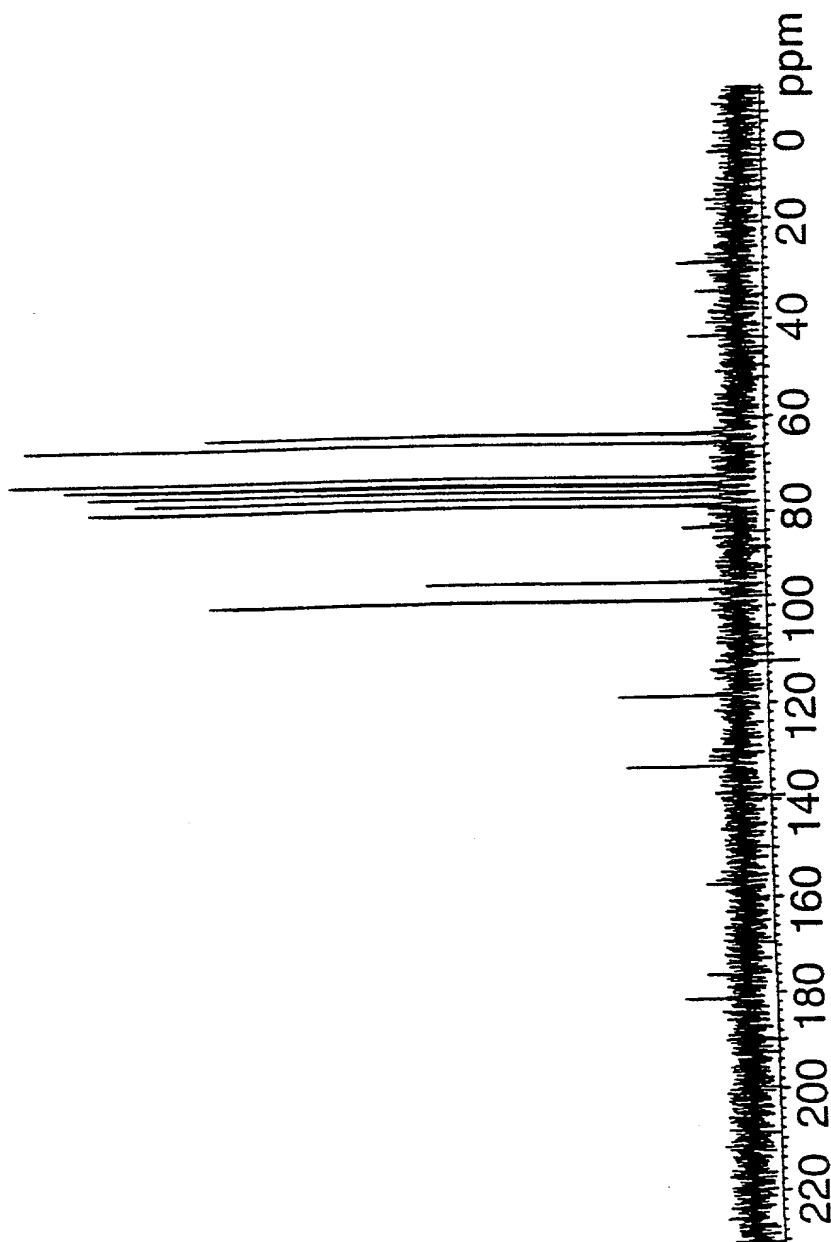


Figure 5b

9/23

T05207 90E06360

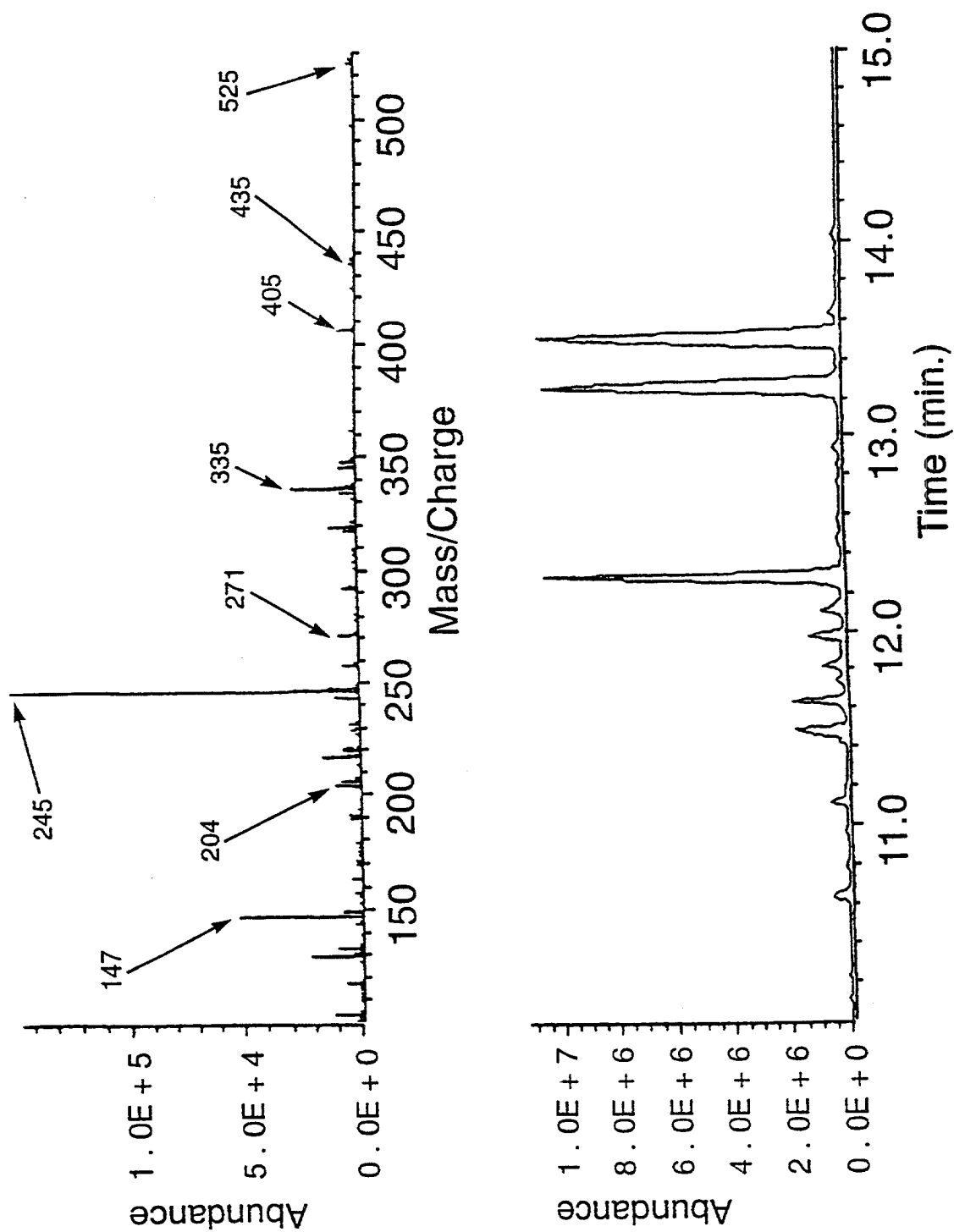
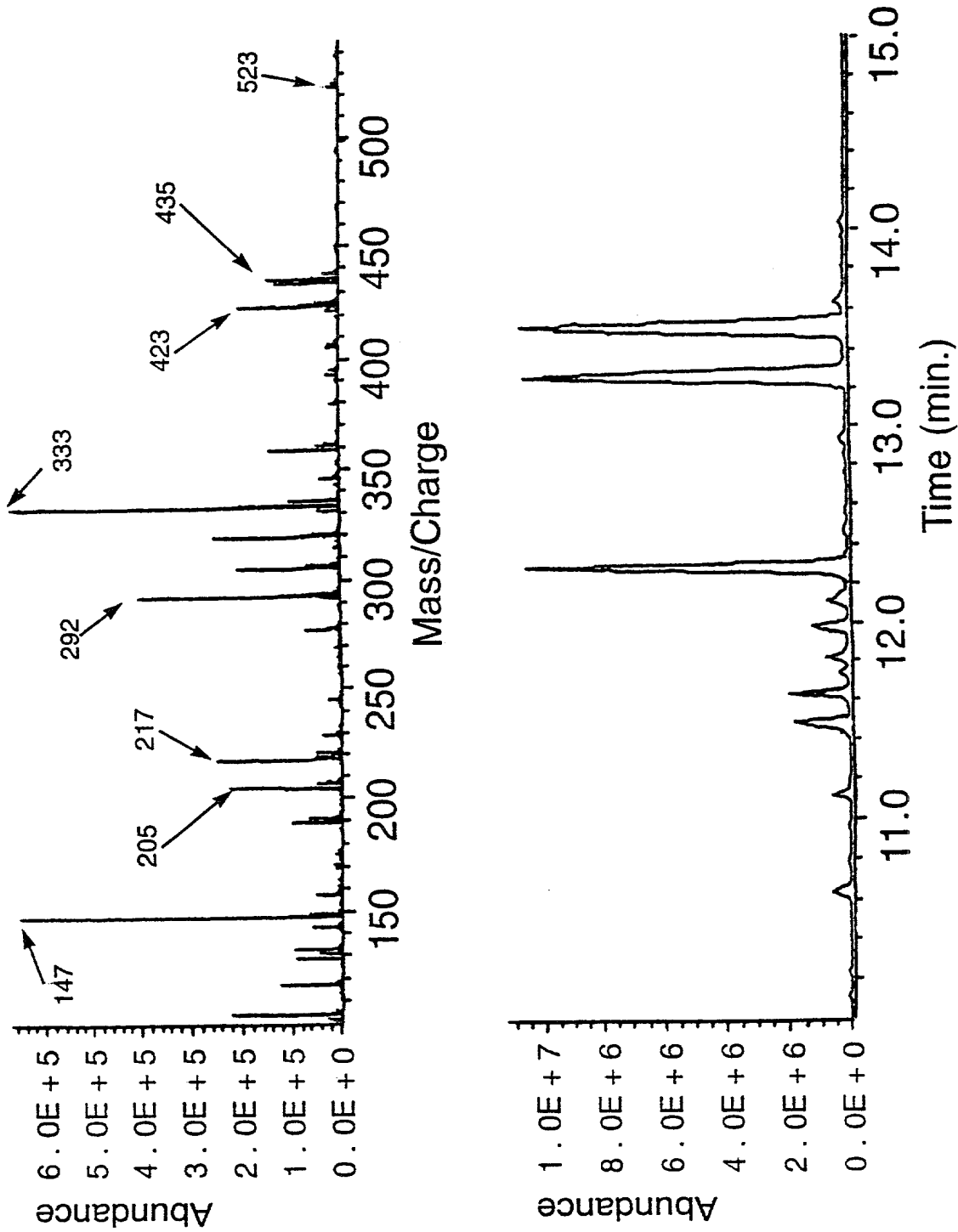


Figure 5c

10/23



11/23

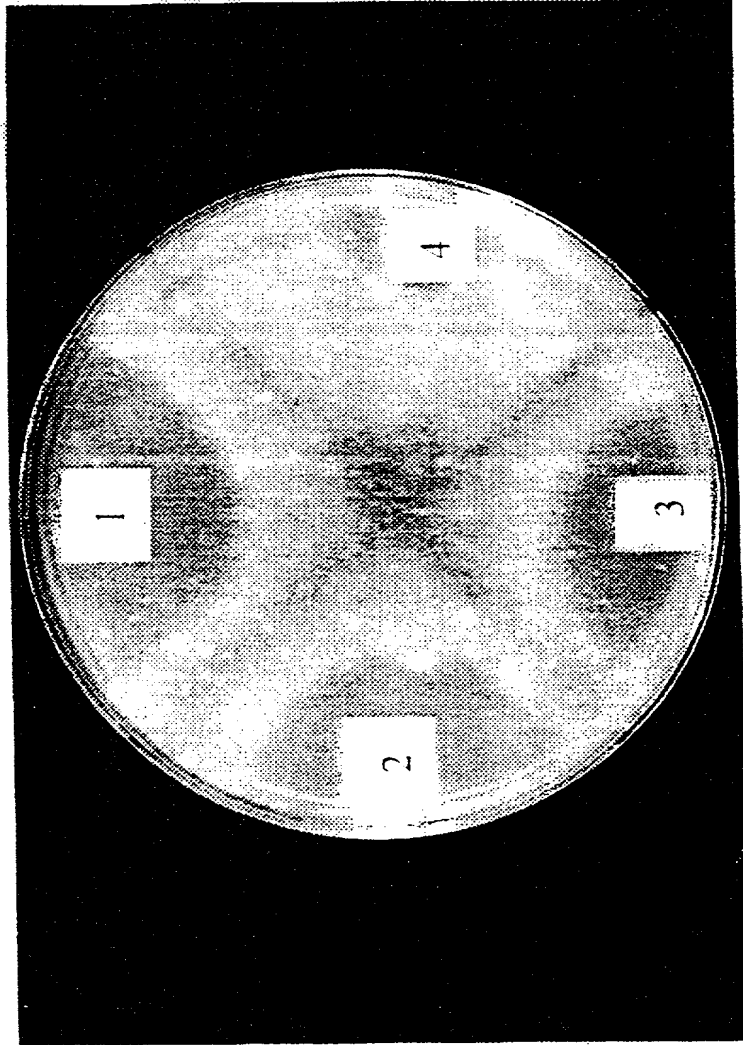


FIGURE 6A

09890306 000046 PCT/AU WO 00/44230

09/890306

WO 00/44230

PCT/AU00/00046

12/23

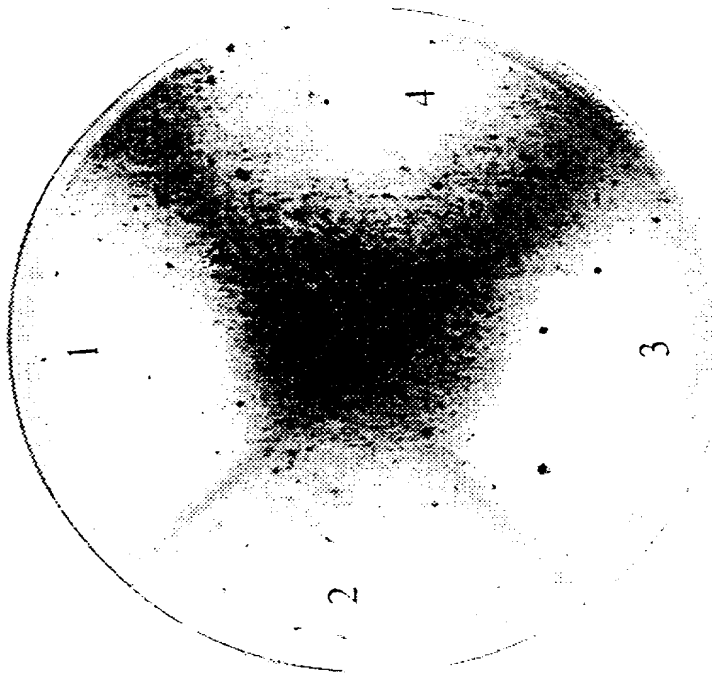
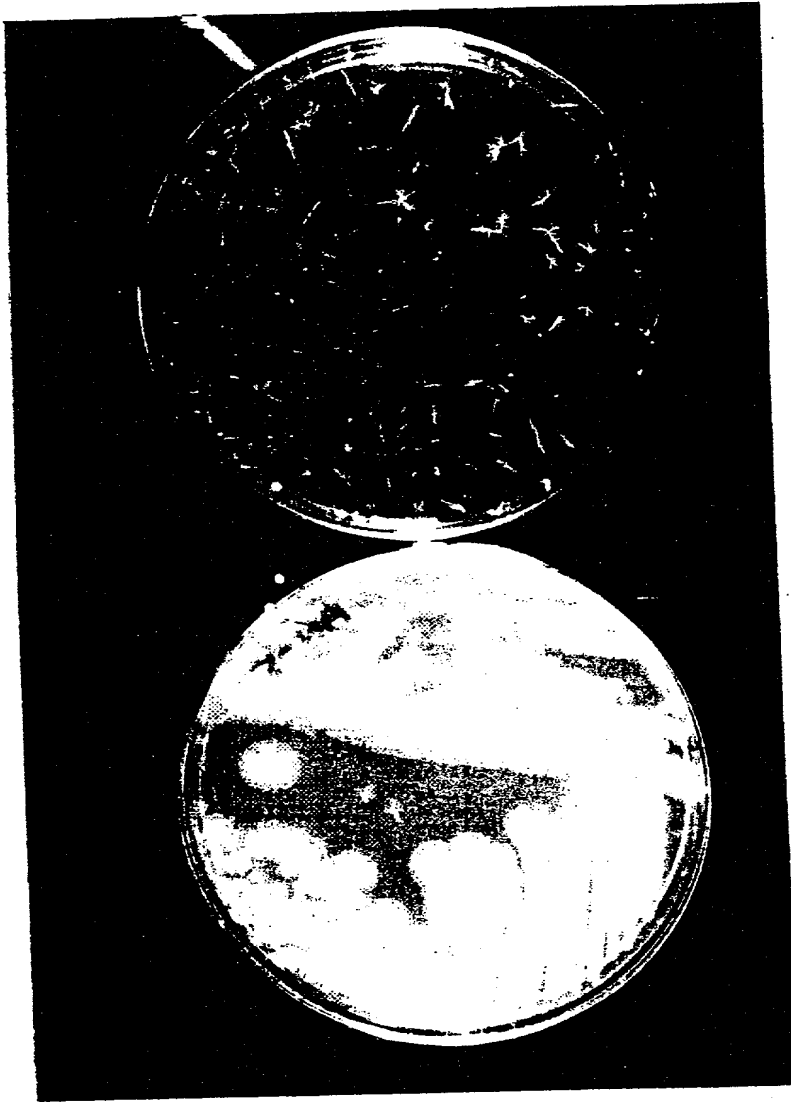


FIGURE 6B

09890306



(b)

(a)

FIGURE 7

14/23

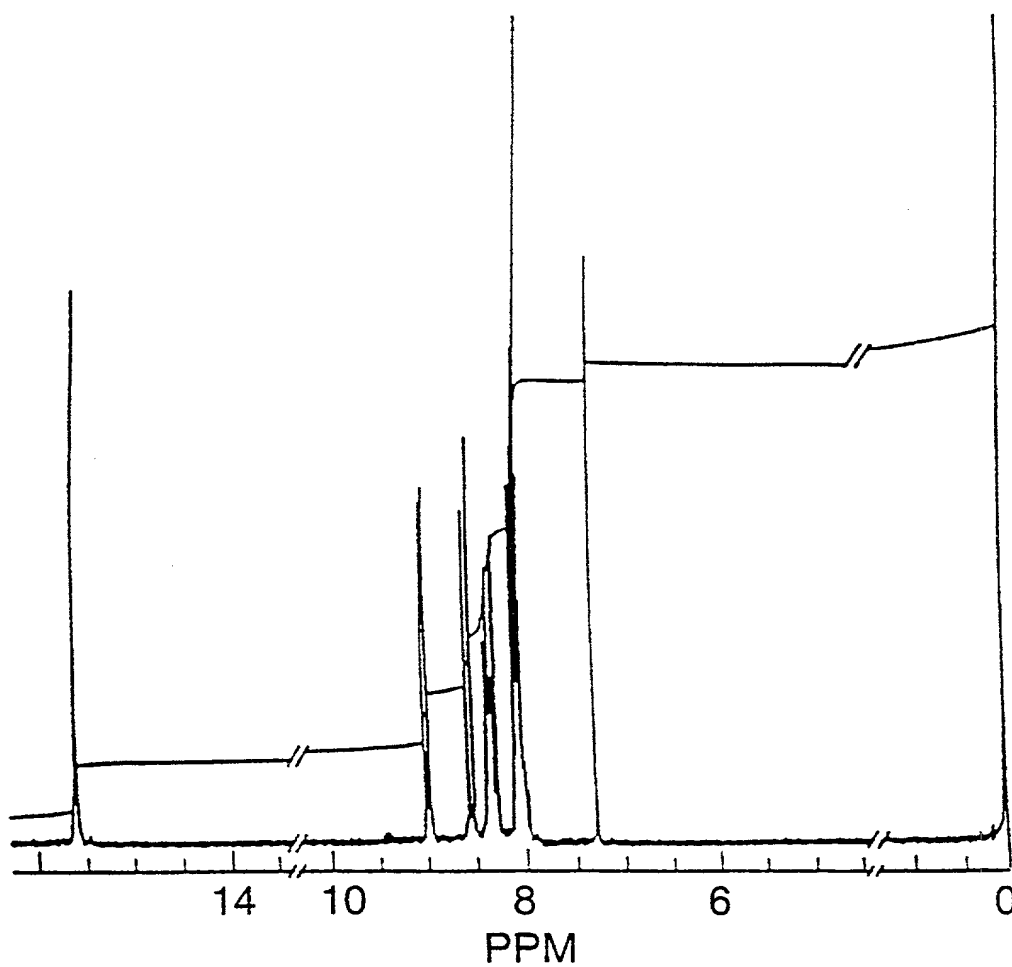


Figure 8

SUBSTITUTE SHEET

15/23

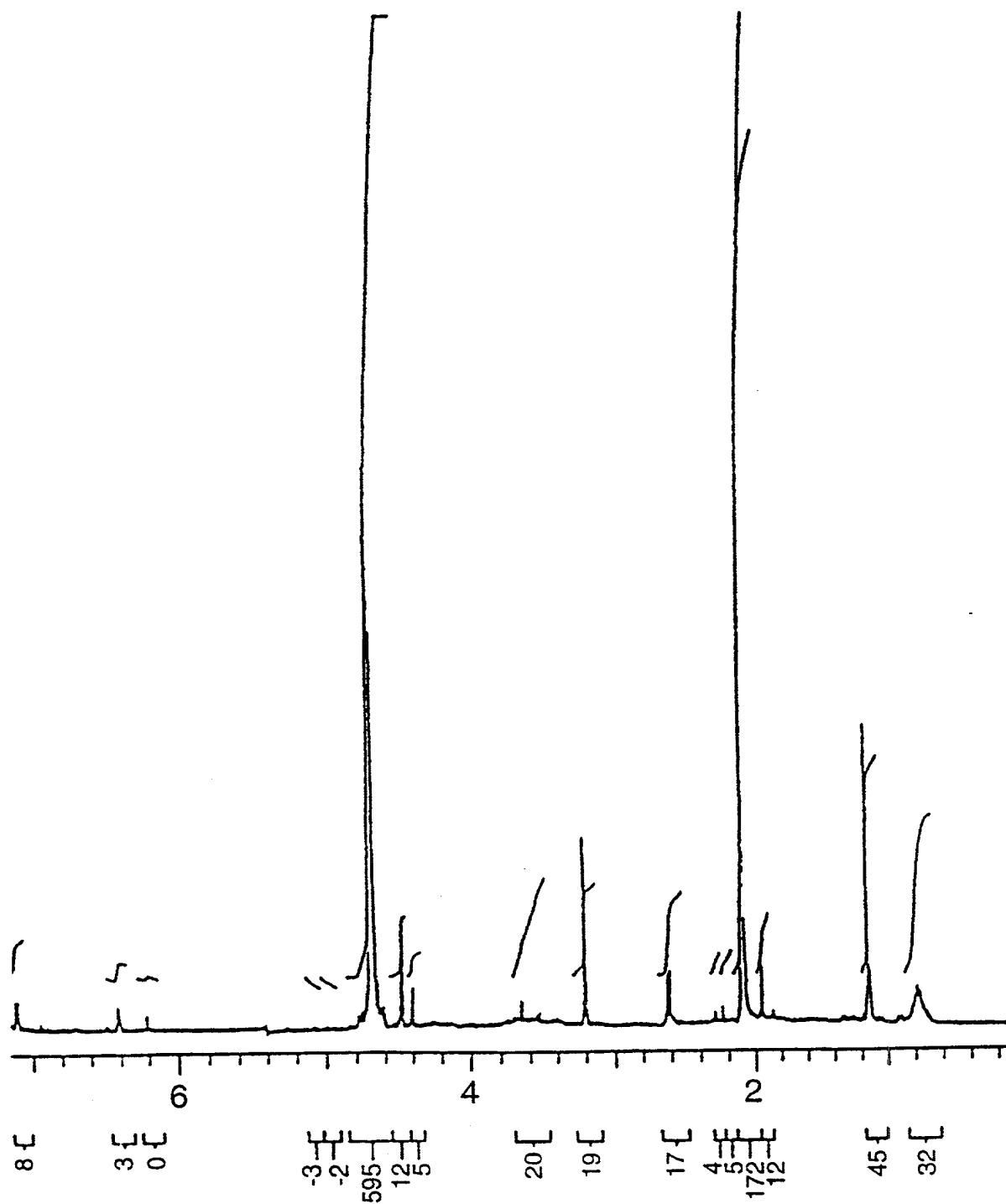


Figure 9a

SUBSTITUTE SHEET



16/23

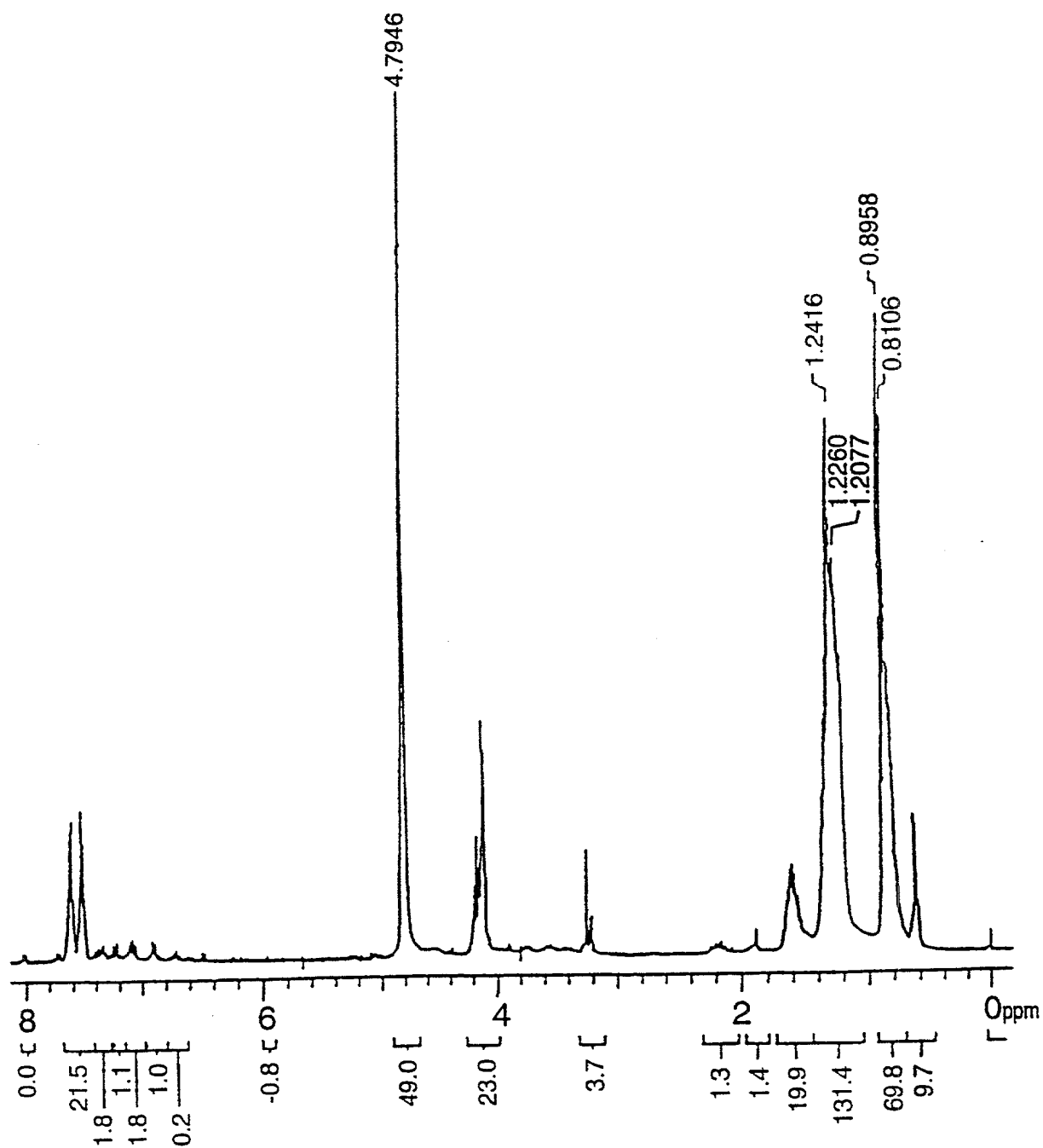
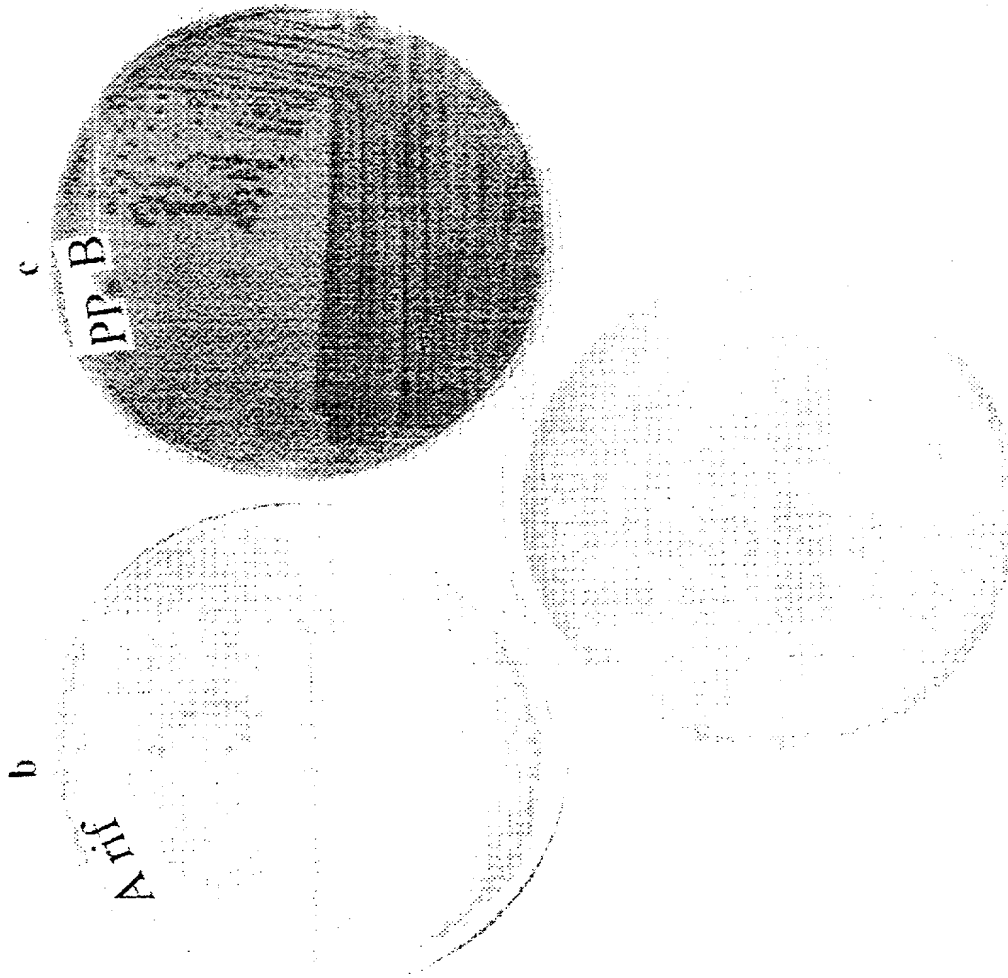


Figure 9b

SUBSTITUTE SHEET



a  
FIGURE 10A

T0520T\* 90E06B60

18/23

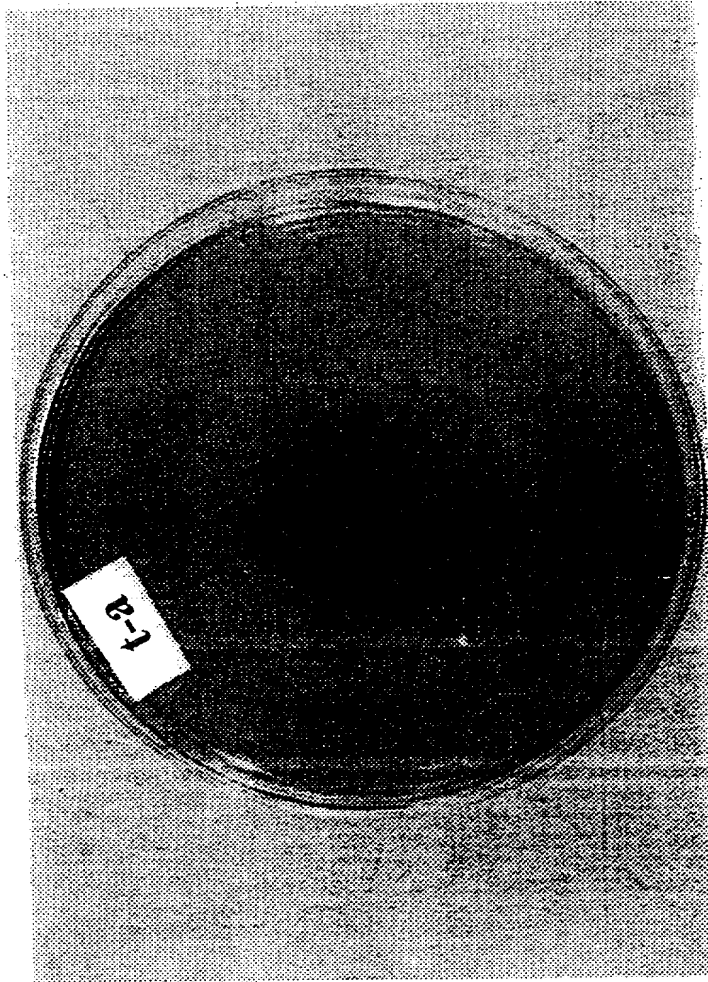


FIGURE 10B

09890306 105201 90E06860

19/23

(411) Scan 12.038 min. of DATA:@GALA.D

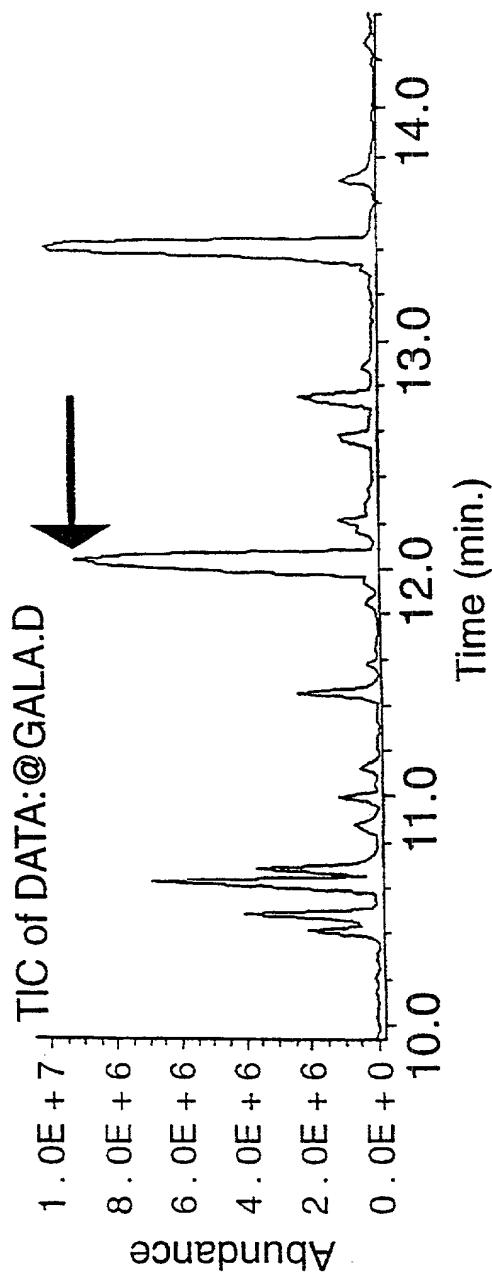
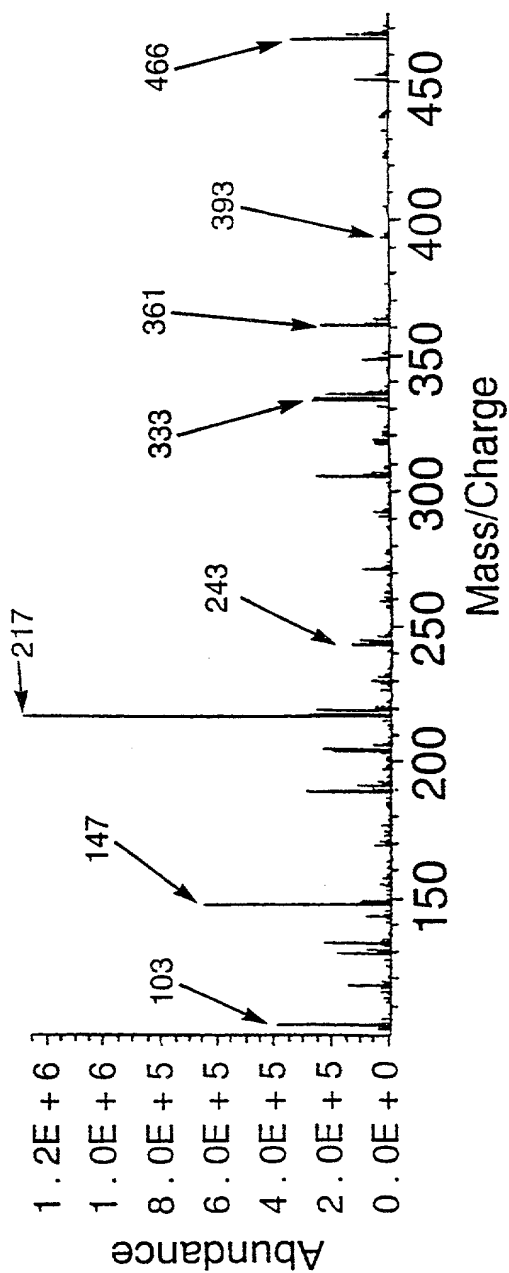


Figure 11a

FOUO 90E05860

20/23

(466) Scan 13.379 min. of DATA:@GALA.D

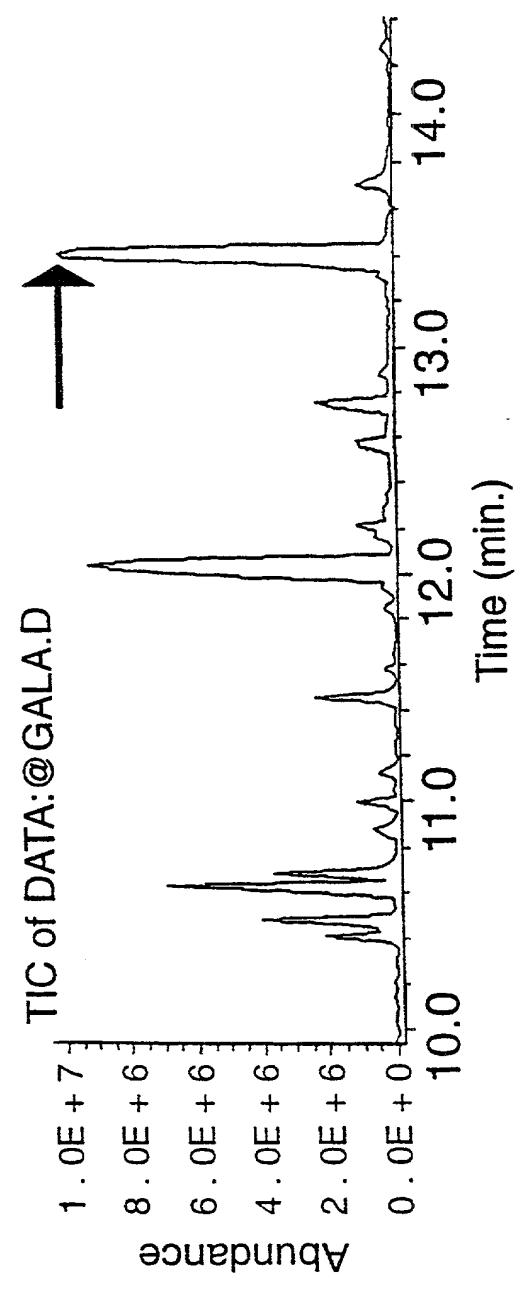
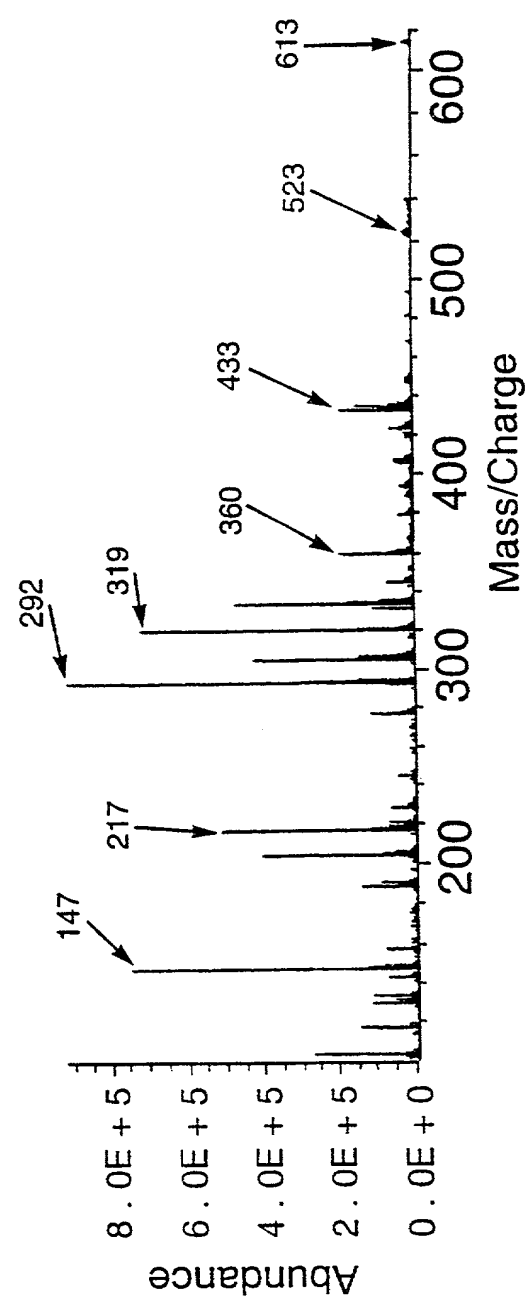
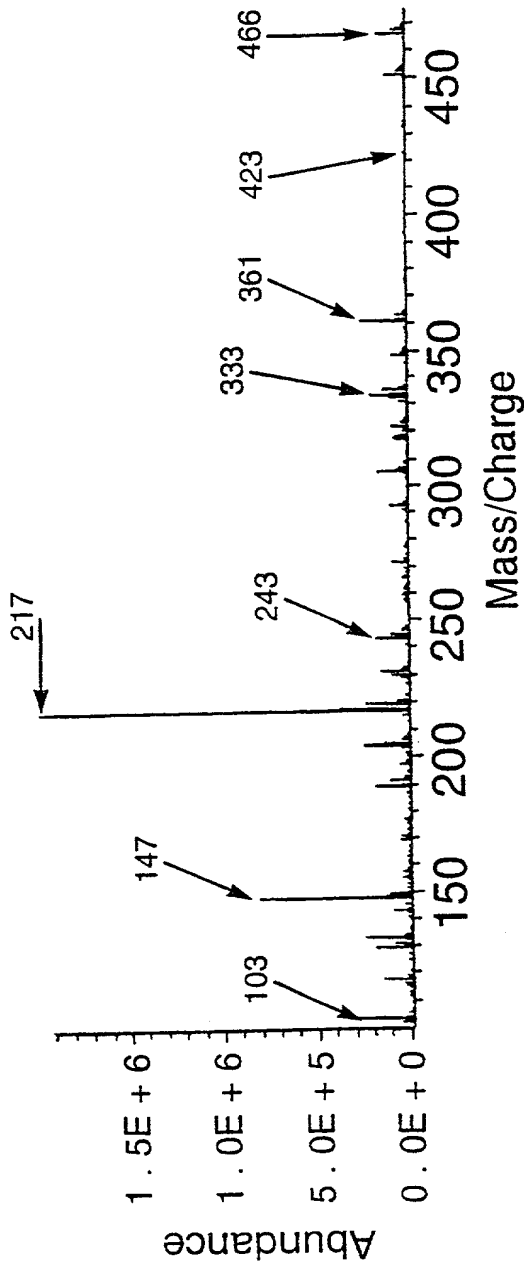


Figure 11b

21/23

(449) Scan 12.954 min. of DATA:@MANNA.D



TIC of DATA:@MANNA.D

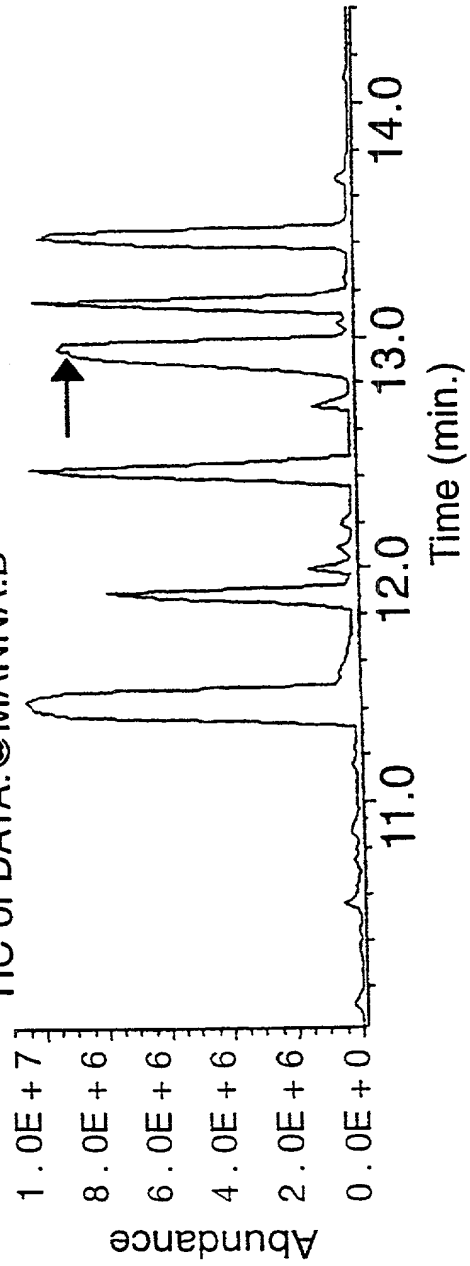
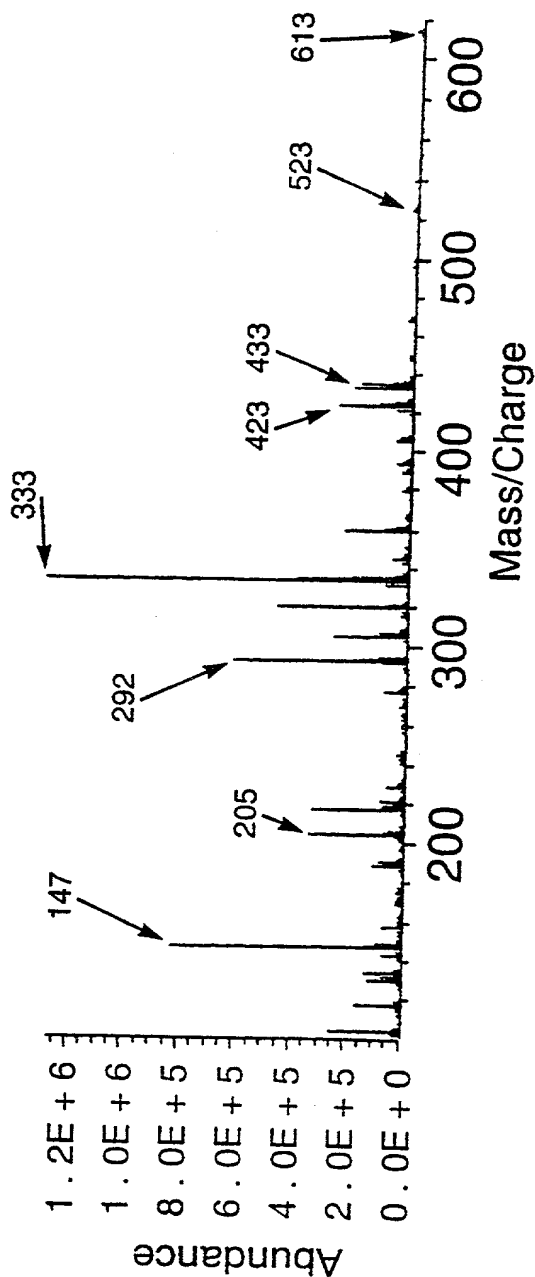


Figure 12a

(457) Scan 13.154 min. of DATA:@MANNA.D



TIC of DATA:@MANNA.D

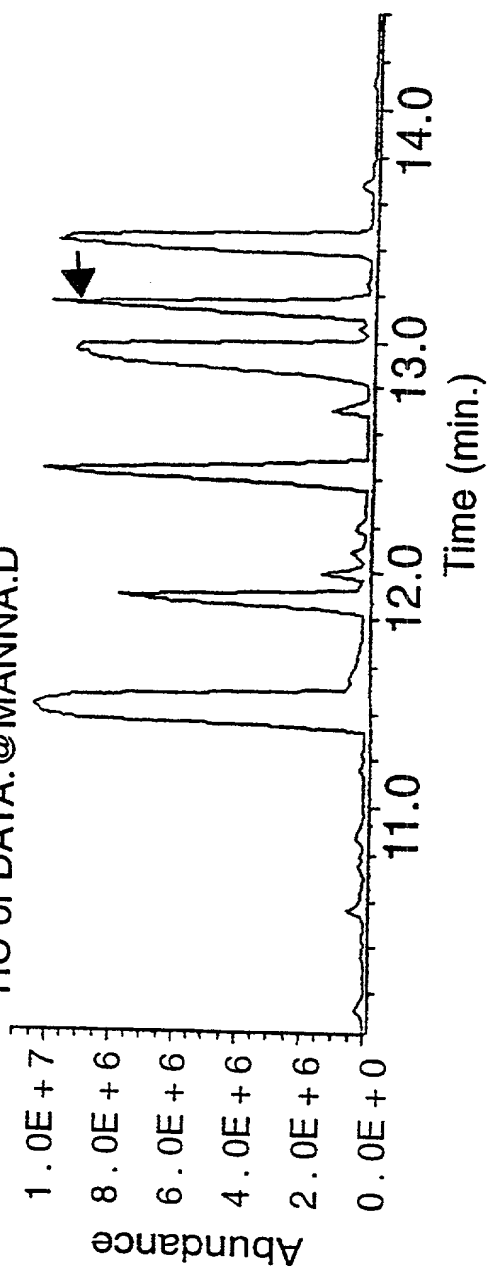


Figure 12b

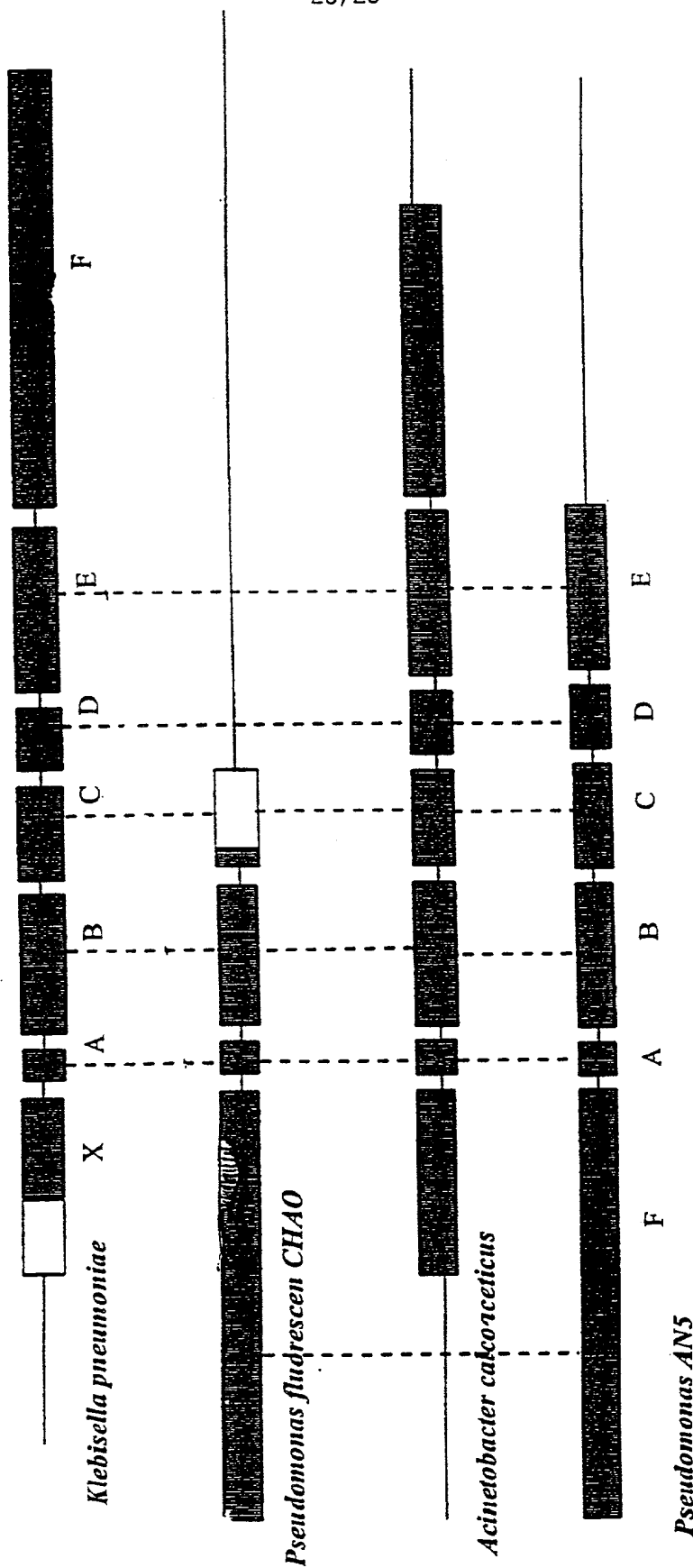


FIGURE 13



My residence, post office address and citizenship are as stated below next to my name.

1990-1991		1991-1992		1992-1993		1993-1994		1994-1995		1995-1996		1996-1997		1997-1998		1998-1999		1999-2000		2000-2001		2001-2002		2002-2003		2003-2004		2004-2005		2005-2006		2006-2007		2007-2008		2008-2009		2009-2010		2010-2011		2011-2012		2012-2013		2013-2014		2014-2015		2015-2016		2016-2017		2017-2018		2018-2019		2019-2020		2020-2021		2021-2022		2022-2023		2023-2024		2024-2025		2025-2026		2026-2027		2027-2028		2028-2029		2029-2030		2030-2031		2031-2032		2032-2033		2033-2034		2034-2035		2035-2036		2036-2037		2037-2038		2038-2039		2039-2040		2040-2041		2041-2042		2042-2043		2043-2044		2044-2045		2045-2046		2046-2047		2047-2048		2048-2049		2049-2050		2050-2051		2051-2052		2052-2053		2053-2054		2054-2055		2055-2056		2056-2057		2057-2058		2058-2059		2059-2060		2060-2061		2061-2062		2062-2063		2063-2064		2064-2065		2065-2066		2066-2067		2067-2068		2068-2069		2069-2070		2070-2071		2071-2072		2072-2073		2073-2074		2074-2075		2075-2076		2076-2077		2077-2078		2078-2079		2079-2080		2080-2081		2081-2082		2082-2083		2083-2084		2084-2085		2085-2086		2086-2087		2087-2088		2088-2089		2089-2090		2090-2091		2091-2092		2092-2093		2093-2094		2094-2095		2095-2096		2096-2097		2097-2098		2098-2099		2099-2100		2100-2101		2101-2102		2102-2103		2103-2104		2104-2105		2105-2106		2106-2107		2107-2108		2108-2109		2109-2110		2110-2111		2111-2112		2112-2113		2113-2114		2114-2115		2115-2116		2116-2117		2117-2118		2118-2119		2119-2120		2120-2121		2121-2122		2122-2123		2123-2124		2124-2125		2125-2126		2126-2127		2127-2128		2128-2129		2129-2130		2130-2131		2131-2132		2132-2133		2133-2134		2134-2135		2135-2136		2136-2137		2137-2138		2138-2139		2139-2140		2140-2141		2141-2142		2142-2143		2143-2144		2144-2145		2145-2146		2146-2147		2147-2148		2148-2149		2149-2150		2150-2151		2151-2152		2152-2153		2153-2154		2154-2155		2155-2156		2156-2157		2157-2158		2158-2159		2159-2160		2160-2161		2161-2162		2162-2163		2163-2164		2164-2165		2165-2166		2166-2167		2167-2168		2168-2169		2169-2170		2170-2171		2171-2172		2172-2173		2173-2174		2174-2175		2175-2176		2176-2177		2177-2178		2178-2179		2179-2180		2180-2181		2181-2182		2182-2183		2183-2184		2184-2185		2185-2186		2186-2187		2187-2188		2188-2189		2189-2190		2190-2191		2191-2192		2192-2193		2193-2194		2194-2195		2195-2196		2196-2197		2197-2198		2198-2199		2199-2200		2200-2201		2201-2202		2202-2203		2203-2204		2204-2205		2205-2206		2206-2207		2207-2208		2208-2209		2209-2210		2210-2211		2211-2212		2212-2213		2213-2214		2214-2215		2215-2216		2216-2217	
-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--

I acknowledge the duty to disclose all information I know to be material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

<u>Country</u>	<u>Application No.</u>	<u>Filing Date</u>	<u>Priority Claimed</u>
WIPO	PCT/AU00/00046	January 28, 2000	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
Australia	PP 8394	January 29, 1999	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No

6

Eric Prah, Reg. 32,590  
Frank R. Occhiuti, Reg. 35,306  
Harold H. Fox, Reg. No. 41,498

Address all telephone calls to Y. ROCKY TSAO at telephone number (617) 542-5070.

Address all correspondence to Y. ROCKY TSAO at:

FISH & RICHARDSON P.C.  
225 Franklin Street  
Boston, Massachusetts 02110-2804

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

**Combined Declaration and Power of Attorney**

Page 2 of 2 Pages

1-00  
Full Name of Inventor: MURALI NAYUDU

Inventor's Signature: x *Murali Nayudu*  
Residence Address: 5 Prout Place, Weston, Canberra, ACT 2611, Australia  
Citizenship: Australia  
Post Office Address: 5 Prout Place, Weston, Canberra, ACT 2611, Australia

Date: x 28 Sept 2001  
*AUX*

2-D  
Full Name of Inventor: RAJVINDER KAUR

Inventor's Signature: x *Rajvinder Kaur*  
Residence Address: 9 Liffey Circuit, Kaleen, Canberra, ACT 2617, Australia  
Citizenship: Australia  
Post Office Address: 9 Liffey Circuit, Kaleen, Canberra, ACT 2617, Australia

Date: x 28 Sept 2001  
*AUX*

20306715.doc

20306715.doc

[illegible]

- 2 -

tactgtgccg cgcctgggcc cgcaggctgc cgttgcgaaa acctgcgcaa ttggcgcaaa 60  
gcagttccat tgaggaaaac cgcgccacgc ggcggaacct agaactctgca ccaacatggc 120  
cgctccatct gcaaaccgaa ataaaaaacg ccccggtga ccgaggcgtt tgctgcgcat 180  
tcaaccgact gcagcaatca acggctggcg aagtacatgg tgaactcgaa accgatacgc 240  
aggtcgatat atgcgggttt ggaccaggac atggaaatac tcctttggtt ggggtgggac 300  
ggttgagatc tatacatata gtccacctcc gttcggagat gttcagatgc ttaggctgct 360  
atggtactaa attaaacaaa atcgcacgcc tcgattctcc ganaaaagct cattgcagac 420  
gctggaatga tcatttcggc atgtgccaat gttcatcccg ggcaaacacc gttgctcagg 480  
caataccggc caccttcggc gtcgatca 508

&lt;210&gt; 3

&lt;211&gt; 660

&lt;212&gt; DNA

<213> *Pseudomonas* sp.

&lt;400&gt; 3

ttaattcgta ggccatgctc atcgcatcga gcatgctcca gagaatgtcc agcttgaact 60  
ggagaatctc cagcatgtgc tcctggcccgc cgcgggtggt gtaatgtgc aaggtaatcg 120  
ccaggccatg ctccacgtca cgcggggcct gaccgaggcg ggtgcggaag tattcataac 180  
cggccggatc gatccacggg tagtgctgtg gccaaactgc caggcgcgac tgatggatct 240  
gcgccgcgaa cagctcggtc agcgagctac tggcggcttc ctgccaactg gcccggcgag 300  
cgaagttgac gtaggcatcc acggcgaatc gcacccctgg cagcaccaat tcctgggagc 360  
gcagttgatc gggatccaac cccacggcct ggcccaaccg cagccaggcc tcgatgccgc 420  
cgtcttcgcc ggggtgcgcc tcattggtcga gcaggcgcgt gatccactcg cgacggatct 480  
cccgatccgg gcagttggcc aggatcgcg catccttcag cggaatgttc acctgatagt 540  
aaaagcgggt ggcgaccag ccctggattt gctcgcgagt ggcacggcct tcatacatcg 600  
ccacgtgata cggatgatgg atgtggtaat acgcgccctt ggcttcgcag ggcccgtttc 660

&lt;210&gt; 4

&lt;211&gt; 315

&lt;212&gt; DNA

<213> *Pseudomonas* sp.

&lt;400&gt; 4

taaggatgca caaaacaaa acccctcgct ggcgccccgc ctatcgcttc cagtacgaac 60  
cggcgagaa aggtcatgtg ttgctctatc ctgaaggcat gatcaagctc aacgacagcg 120  
ctgcgtgat cggcggcctg atcgacggtg aacgggatgt cgcagccatc atcggcgagc 180  
tggccaagca gtttcccgac gtgcccgaac tcggtgacga catcgagcag ttcattggagg 240  
tcgcccgtgc agagcattgg atcgaacttg cctgaccagc cagcgatcgg cttgcccgtg 300  
tggttgctgg cgagag 315

&lt;210&gt; 5

&lt;211&gt; 810

&lt;212&gt; DNA

<213> *Pseudomonas* sp.

T0520T" 90E06960

- 3 -

&lt;400&gt; 5

tgcaggtggc gagctcgacg aagtcggcct caagggcaat gcacagctcg atgatgcggt 60  
cgatcttgtc gatgtgtgtc cgatgggtaa cgaagttgag caccatcggg tagccgtggg 120  
ccttcaactgc ccggggccatt tccagcttct gtgcgaaggc tttcttcgag ccggccagca 180  
ggttgttcac ctgttcgtcg ctggcctgga agctgatctg gatatgatcg aggcggcct 240  
tcttgaagtc gctgattttc tgttcggtca aaccgatgcc ggaggtgatc aggttggtgt 300  
agaaacccaa cttgcgcgcc tcgcgatca gttcggcgag gtcctggcgc accagcggtt 360  
cgccaccgga aaagcccagc tgcgcggcgc ccatttccct ggcttcgca aagaccttga 420  
accactgctc ggtgctcagc tccttgccct gtcggcgaa gtccagcggg ttggaacagt 480  
aggggcattg cagcgggcaa cgataggtca gtcgccag caaccacagc ggcaagccga 540  
tcgctggctg gtcaggcaag ttcgatcaa tgctctgcac gggcgacctc catgaactgc 600  
tcgatgtcgt caccgagttc ggcagctcgg gaaactggtt ggccagctcg ccgatgatgg 660  
ctgcgacata ccgttaccgt cgatcaggcc cgccgatcaa cgcaacgctt gcgttgaact 720  
tgatcatgcc ttccaggaaa aaaacaaaca catgaccttt gtgcgcccg ttcgtacttg 780  
gaaagcgata agccggggcc gccaacggaa 810

&lt;210&gt; 6

&lt;211&gt; 354

&lt;212&gt; DNA

<213> *Pseudomonas* sp.

&lt;400&gt; 6

gttactaaat taaacaaaat cgcacgcctc gattctccga gaaagctcat tgcagacgct 60  
gtaatgatca tttcggcatg tgccaatgtt catccgggca aacaccgttg ctcaggcaat 120  
accggccacc ttcggcgctc atcaggcgtc ggggtggcatc gagcaattgc ttgcgattca 180  
atcctgcgat cgcacgcaa agttgctcaa ggtaatccga cggcgggccg gccagtttac 240  
cctgccaaag caattcggcc gttgggcgca gggcaagggtg tcgcttgtga aactgggagg 300  
cgaagtgcc gttgctgggt cgagcaaggc cgaatcgctg acctgtcgga tcag 354

T032T "S0E06660